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Technology, Innovation, and Regional Economic Development

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Foreword

This report assesses the potential for local economic growth offered by high-technology industries, the types of programs used by State and local groups to encourage development of these industries, and the implications of these programs for Federal policy. As such, it is a companion to the continuing series of OTA reports on the international competitiveness of U.S. industry and the meaning of industrial policy in the U.S. context. It was requested by the House Committee on Science and Technology, and letters of endorsement were also received from the House Committee on Small Business; the House Task Force on Industrial Innovation and Productivity; the Joint Economic Committee; and the House Committee on Banking, Finance, and Urban Affairs.

In recent years State and local governments, universities, and private sector groups have become increasingly active in promoting technological innovation and technology-based business development in their local economies. These efforts have resulted in productive new forms of partnership and cooperation at all levels. While Federal programs have sometimes supported these efforts, and while recent changes in Federal policy have improved the climate for high-technology development initiatives, in most cases both the initiative and the ongoing leadership have come from imaginative State and local leaders. OTA hopes that, by documenting these efforts, it can help Congress to take State and local efforts and perspectives into full consideration in the formulation of national policy.

OTA was assisted in this assessment by an advisory panel of individuals representing a wide range of backgrounds, including industry, finance, and State and local government. In addition, hundreds of State and local officials have provided information and dozens of reviewers from universities, private companies, and government agencies have provided helpful comments on draft reports. OTA expresses sincere appreciation to each of these individuals. As with all OTA reports, however, the content is the responsibility of OTA and does not necessarily constitute the consensus or endorsement of the advisory panel or the Technology Assessment Board.

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CHAPTER 1

Overview of High-Technology Development

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CHAPTER 1

Overview of High-Technology Development

OTA's investigation of regional high-technology development (HTD) suggests that high-technology industry is so difficult to define and isolate statistically, and so interdependent with other sectors of the economy, that to define Federal policy for regional development based on distinctions between "high technology" and "low technology" would be artificial and possibly misleading. By any definition used today, high-technology industries are expected to grow somewhat faster than will overall employment over the next decade. Because of their relatively small employment base, however, these industries will directly account for only a small fraction of total employment growth. It is likely that their largest employment impacts will come through the diffusion and widespread application of their products by other industries, "smokestack" and services alike.

In short, while high-technology industries may contribute significantly to the productivity and competitiveness of the overall economy, an emphasis on those industries per se, rather than on the process of technological innovation and diffusion, carries a risk of distorting public policy and ignoring real opportunities for promoting industrial competitiveness and sustainable economic development.

High-technology industries do represent an important component in some regional economies. They are becoming more dispersed geographically,

Photo credit: RCA

High-technology complex

but few communities are likely to develop large concentrations of microelectronics- and computer-based firms like those in California's Silicon Valley or Massachusetts' Route 128. New opportunities for economic development are being created by other emerging technologies, and even greater opportunities exist for the application of productivity-enhancing innovations in existing industries. Accordingly, the greatest opportunities for most communities may lie in encouraging business development and technological innovation *throughout* the local economy, rather than simply attracting high-technology businesses from other regions.

State and local groups have taken the initiative in launching programs to promote technological innovation in their economies. While some of these initiatives were no doubt inspired by the successes of other regions, they are usually seen as logical extensions of traditional economic development activities. Most HTD initiatives attempt to mobilize available resources or to create the institutional networks that encourage innovation and entrepreneurship. The diversity and flexibility of these initiatives reflect the inventiveness of local leaders, as well as the need to adapt to prevailing needs and conditions in widely different areas. These initiatives have considerable potential to stimulate technological innovation, and in some regions they have already proven to be a useful complement to existing economic development programs. To the extent that these State and local initiatives can stimulate the national level of research and development (R&D) and quicken the pace of commercialization and diffusion of new technologies, they may also contribute to the productivity of the entire U.S. economy.

Federal policies and programs have contributed to regional HTD, usually as an indirect result of attempts to achieve broader national goals and purposes. For example, innovation-oriented policies—those intended to promote R&D and technological change at the national level—often have significant impacts on regional development. Similarly, community and economic development programs—e.g., block grants, business assistance, and education and training—have sometimes stimulated technological innovation in local economies. Macroeconomic policies of the Federal Government have had perhaps the largest and least intentional influence on regional HTD. Relatively little Federal effort has gone toward promoting technological innovation and regional development *concomitantly;* the few Federal programs to do so have been largely experimental in nature, and designed to develop or support State and local mechanisms.

However, OTA finds no evidence that an extensive new Federal effort, *specifically and directly* targeted on this aspect of economic development, would be necessary to promote regional HTD. Several recent changes in Federal policy promise to create a better climate for State and local HTD initiatives. Many additional changes that have been proposed for larger Federal policies and programs, *to achieve broader national objectives,* might also provide additional indirect benefits for regional HTD.

Thus, it would seem most effective to continue current Federal roles, and where possible improve those roles by making Federal policies and programs more sensitive to their regional impacts. *Better information* would help to identify and refocus existing policies and programs that can contribute to regional HTD; such information would also be useful to State and local clients. Much could also be achieved through *improved coordination* of existing policies and programs, perhaps as part of a mechanism created to pursue objectives relating to industrial policy, and/or improved coordination with State and local mechanisms, which may provide an effective means of achieving national goals in the area of regional HTD. These conclusions are based on the principal findings outlined below. Implications for Federal policy are developed at the end of this chapter.

Findings

1. State and local groups have become increasingly active in encouraging technological innovation and high-technology development.

Encouraged by the success of such areas as Silicon Valley and Route 128, public and private sector groups in other regions are launching initiatives to promote HTD in their own economies. The growing competition for HTD has generated literally hundreds of these initiatives by State and local governments, universities, and private sector organizations. State and local leaders are attracted to HTD because they believe it promises new jobs, clean industry, and rapid growth. Some also believe that high-technology businesses can be a major force in the revival of distressed regions and cities, especially in the Midwest.

These initiatives are seen as a logical and inevitable extension of more traditional economic development activities. They vary in their goals and results, in part because they must be adapted to the prevailing conditions and available resources in widely different areas. The diversity of these efforts, and the flexibility with which specific programs have been structured, suggest that they are usually based on a careful evaluation of a region's needs and its existing industrial base. Many have considerable potential to stimulate technological innovation, and in some regions they have already proven to be a useful complement to existing economic development programs. In a number of specific program areas, innovative State and local strategies appear to be making a major contribution to regional HTD.

2. The efforts of State and local groups to promote high-technology development in their regions may have implications for the national economy.

High-technology industries are a key source of the innovative ideas, products, and processes that are essential to revitalizing older industries and maintaining U.S. technological and economic competitiveness. State and local HTD initiatives naturally are primarily concerned with regional economies, but to the extent that these activities increase the level of R&D or quicken the pace of commercialization and diffusion of new technologies, they may also have potential for improving the productivity and competitiveness of the entire U.S. economy.

3. Depending on the definition of high technology used, jobs in high-technology industries currently represent between 3 and 13 percent of total U.S. employment.

According to three definitions used by the U.S. Bureau of Labor Statistics (BLS), high-technology industries represented 2.5 million, 5.7 million, or 12.3 million jobs in 1982, out of a total wage and salary employment of 92 million.

4. Employment in high-technology industries grew at a faster rate over the past decade than did overall employment, and it is likely to continue doing so in the coming years. Nonetheless, because high-technology industries are a small sector of our economy, they will directly provide only a small share of total new jobs.

High-technology industries increased their employment by 25 to 40 percent (depending on definition) over the decade between 1972 and 1982; during that time overall employment rose by 20 percent. BLS projections indicate the likelihood of a similar outcome for the period through 1995, although both growth rates are expected to be lower than in the past. For example, the high-technology industries included in the BLS' midrange definition increased their employment from 4.47 million in 1972 to 5.69 million in 1982 (an average growth rate of 2.4 percent a year), and are projected to increase their employment further by 1995 to between 7.72 million and 7.89 million (2.0 to 2.2 percent a year average growth rate); overall employment grew at an average rate of 1.9 percent a year from 1972 to 1982 and is expected to grow by 1.5 to 1.8 percent a year in the near future, adding 25 million new jobs by 1995. By this projection, 8 to 9 percent of new jobs will be in high-technology industries (slightly more than 2 million out of the 25 million total).

It is important to note that the preceding projection of employment in high-technology industries

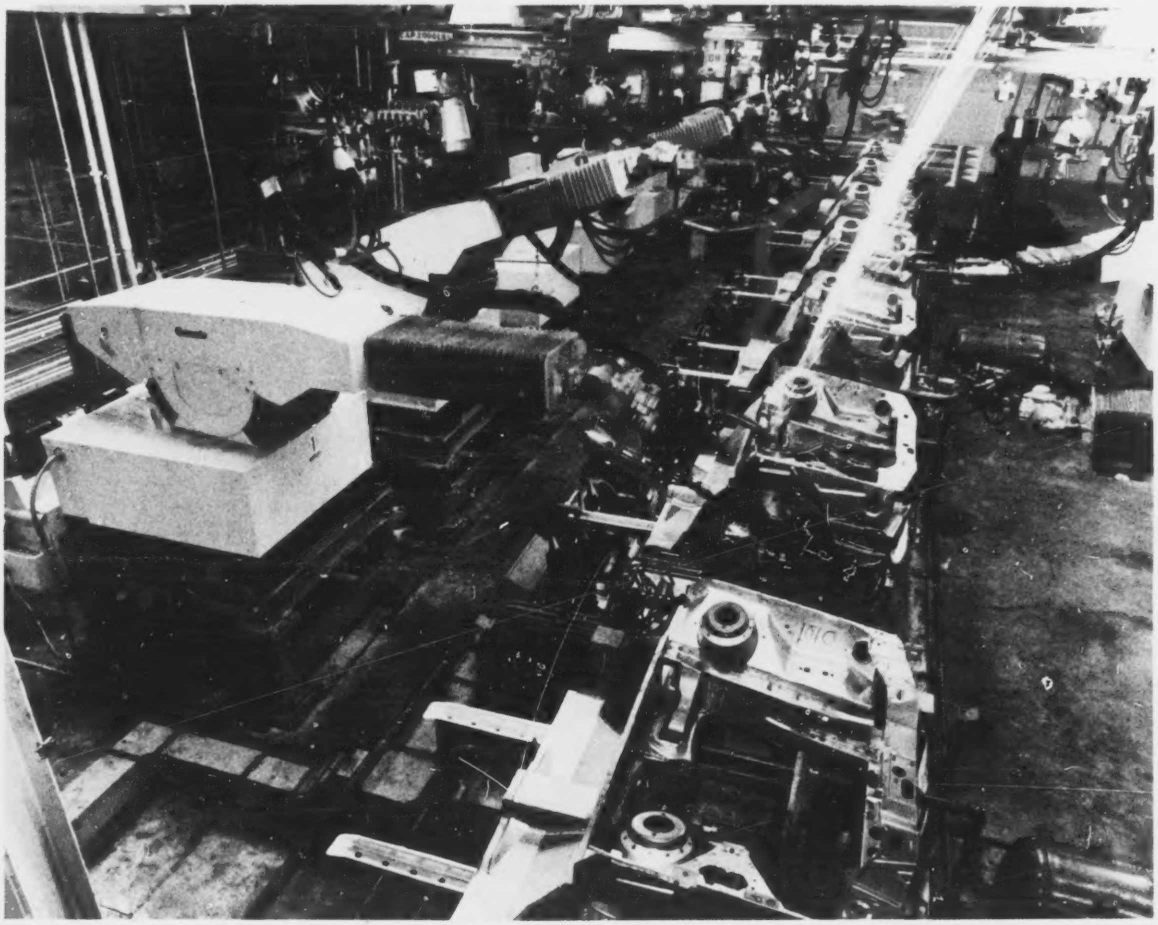

Photo credit: Ford Motor Co.

High-technology innovations can help revitalize older U.S. industries; here, robots weld automobile subframes

does not fully account for the impact of high technology on employment: other new jobs will be created elsewhere in the economy as a result of the use of high-technology products. Unfortunately, this latter effect cannot be quantified.

BLS projections indicate that high-technology industries represent neither the fastest growing employment sector nor the one that will add the largest absolute number of jobs. For example, employment in construction is estimated to increase by 2.6 percent a year, and in service, by 2.1 percent. The non-high-technology portion of the service sector alone is estimated to increase its employment by more than 9 million jobs.

5. Jobs in high-technology industries play a major role in the economies of many States and communities.

Analysis of recent trends shows that some regions and communities benefit more from HTD than others. This is because high-technology employment is concentrated in a few States, and within those States in a few large metropolitan areas. Using a "moderate" definition of high technology, corresponding to about 6 million jobs in 1982, 60 percent of high-technology jobs are located in the 10 States with the highest levels of high-technology employment, and 40 percent in the top five States. Within these States, moreover, as much as 90 percent of high-technology employment is located in the five largest metropolitan areas, some of whose labor forces are one-third in high-technology industries.

6. **High-technology industry employment is found predominantly in large multistate enterprises and became more dispersed geographically during the 1970's.**

According to one study, 88 percent of high-technology employment was found in large multiestablishment firms, compared to 60 percent for all private employment. During the period 1976-80, new and expanding branch facilities were the source of most high-technology employment growth. The South and the West, with the smallest shares of high-technology employment in 1976, had the highest employment growth rates during this period. Another study found that 80 percent of high-technology industries became more dispersed during 1972-77, with some of them opening plants in as many as 100 new counties. However, between 37 and 48 percent of high-technology employment has remained concentrated in the top five States since 1975.

7. **While the conditions that led to concentrations of microelectronics firms in Silicon Valley and Route 128 are unlikely to be replicated in other areas, new opportunities are being created elsewhere by advances in microelectronics and other technologies and in the application of new products and processes by existing industries.**

The emergence of these archetypes was caused by the confluence of *technological opportunity*, created by fundamental advances in microelectronics that opened up a wide range of potential applications, with the *preexisting socioeconomic conditions* in each region. The result was cumulative, leading to *agglomeration economies* that tended to enhance the region's resources and encourage high-technology entrepreneurship. In both regions, growth was driven by "home grown" startups and local spinoffs from firms already in the area.

Many of these conditions cannot be replicated elsewhere, and few other communities are likely to develop such large concentrations of microelectronics and computer firms. Some of the conditions can be replicated, however, and these areas do provide lessons for communities seeking to expand the technological base of their local economies. Furthermore, new technological opportunities are being opened by advances in other fields, such as robotics and biotechnology. Finally, the applications of new products and manufacturing technologies also create new opportunities for basic industries and the regions in which they are concentrated.

8. **The most important conditions for "home grown" HTD are the technological infrastructure and entrepreneurial network that encourage the creation of indigenous high-technology firms and support their survival.**

Many communities are trying to achieve long-term, sustainable high-technology growth by making the transition from branch plants to "home grown" HTD, based on the creation of new firms by local entrepreneurs. Indigenous HTD depends in large part on the community's ability to mobilize and integrate the various resources—scientific, financial, human, and institutional—that constitute the region's technological infrastructure:

- applied research and product development activities at nearby universities, Federal laboratories, and existing firms;
- informal communication networks that provide access to information and technology transfer from those R&D activities;
- scientific and technical labor force, including skilled craftsmen, newly trained engineers, and experienced professionals (who also represent a pool of potential entrepreneurs);
- a network of experts and advisors (often augmented by university faculties) specializing in hardware, software, business development, and venture capital;
- a network of job shoppers and other suppliers of specialized components, subassemblies, and accessories; and
- proximity to complementary and competitive enterprises, as well as distributors and customers.

Entrepreneurs, in general, tend to be moderate risk-takers who function well in a supportive environment where they can obtain the information, resources, and assistance that will give their enterprises a reasonable chance of success. Regional and local cultures can be especially supportive of entrepreneurship: the spinoff and startup of new firms drove the development of Silicon Valley and Route 128. This finding has clear implications for other regions, in that all communities can create support networks, access to information, and other types of resources that may encourage entrepreneurs.

9. Venture capital is becoming more widely available for high-technology firms, although by far the largest amounts are still flowing to firms in California and Massachusetts.

Venture capital plays an important role in the process of HTD, through both investment and business development assistance. Concerns have been raised that gaps in venture capital availability may hinder the creation and expansion of new high-technology firms. These gaps fall into three categories: regional (location), sectoral (technology or industry), and stage of development (especially at the seed or startup stage). There is some indication that market forces are working to correct—not exacerbate—trends concerning these potential gaps. Recent data indicate that investments have risen in almost all regions, but it appears that California investors still generate the most venture capital and California firms still attract much of the investment from other regions. Some State and local programs are designed to encourage local venture capital to "stay at home." Seed capital, invested at the very early stages of a new enterprise, is less well understood but may be more of a problem for local HTD efforts than venture capital.

10. State and local initiatives often involve institutional innovations directed at the conditions thought to be supportive of indigenous HTD.

State and local HTD initiatives are aimed at new starts as well as branch plants. They differ from traditional economic development strategies primarily in their attention to the special needs of high-technology firms and in their emphasis on creating the cooperative institutional networks that constitute the technological infrastructure. These initiatives have resulted in new linkages between government, university, and industry that are aimed at developing and integrating the technical and entrepreneurial resources in their regions. They seek to mobilize resources or remove barriers in six general areas:

- research, development, and technology transfer;
- human capital, including education and training;
- entrepreneurship training and assistance;
- financial capital;
- physical capital; and
- information gathering and dissemination.

11. Federal policies and programs have played an important but usually indirect role in State and local HTD initiatives.

The Federal role in regional HTD is usually indirect, even unintentional, and largely incidental to the pursuit of other and more central national goals and purposes. Moreover, little effort at the Federal level has gone toward promoting technological innovation and regional economic development concomitantly. OTA's investigation has identified four specific areas in which the Federal Government influences regional HTD:

- **R&D and innovation policies,** including not only Federal investments in R&D and tax incentives for private investments in innovation, but also macroeconomic and trade policies and regulatory policies in the areas of patents and antitrust;
- **technology transfer programs** that attempt to increase innovation and growth of industrial sectors by encouraging the diffusion and utilization of federally developed technologies by private industry;
- **general regional development programs,** including block grants and technical assistance, which provide flexible funding tools that have been put to innovative uses in many State and local HTD programs; and
- **planning and demonstration projects** that facilitate new institutional linkages and encourage or support the creation of new HTD mechanisms at the State and local levels, some of which have been continued or copied elsewhere with little additional Federal support or intervention.

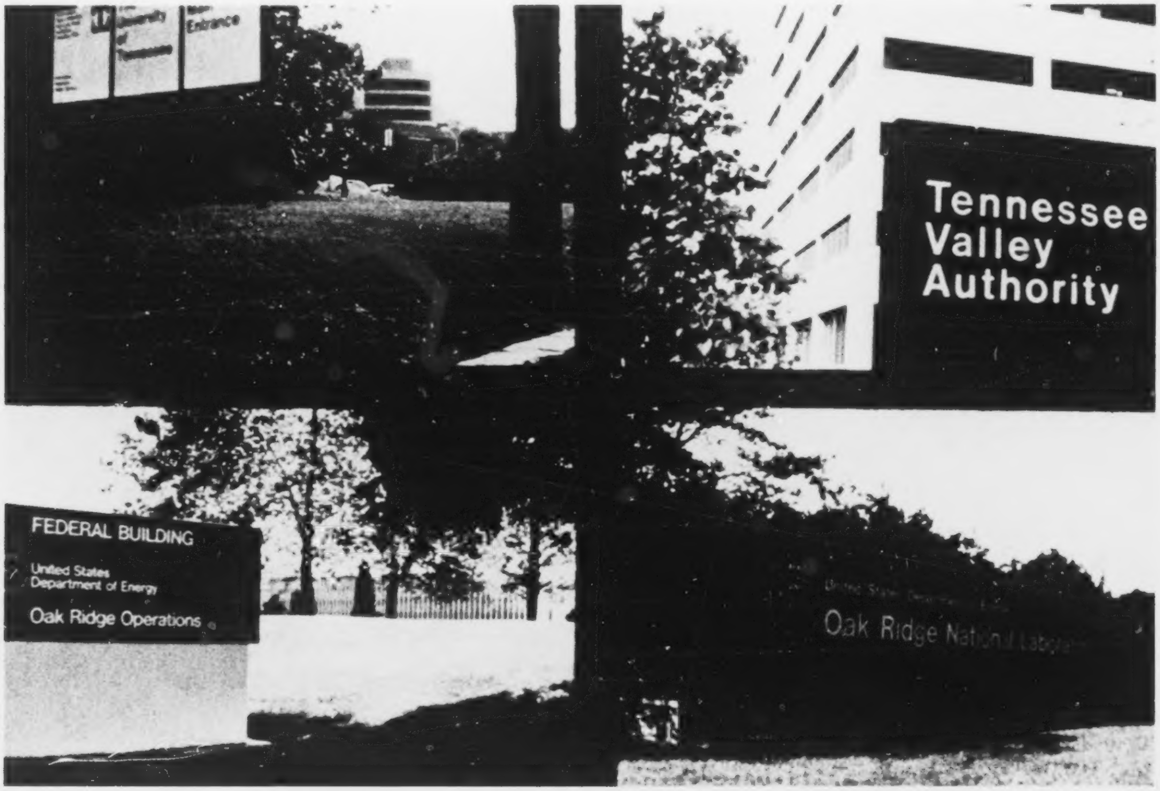

Photo credit: Tennessee Technology Foundation

A region's "technological infrastructure"—its scientific, institutional, human, and financial resources—is important for the development of indigenous high-technology firms

12. The lack of a single, generally accepted definition of "high technology" constrains analysis.

Some of the confusion surrounding the question of HTD stems from the variety of definitions of "high technology" and the vagueness with which the term is sometimes used. For statistical purposes, high-technology industries are usually defined as those industry groups with higher than average R&D spending and/or proportion of scientific and technical workers. High-technology industry is far from homogeneous, however; it is made up of disparate kinds of firms, using varying levels of technology, and producing different kinds of jobs at different times and places. Some of these industries have grown faster than average, others more slowly, and still others have contracted in recent years.

No definition, however, captures adequately the full process of technological innovation. "High technology" can be restricted to a small group of research-intensive industries that manufacture new, sophisticated, technology-intensive products. Alternatively, it can be defined broadly enough to include any industry that employs new methods or machinery. This distinction is important because the *application* of new products and processes usually has larger economic and employment impacts than their development.

13. Statistical evidence relating specific characteristics of communities to regional patterns of high-technology development remains sketchy.

Efforts to correlate specific community characteristics with patterns of HTD indicate that recent population growth—a measure of the area's economic health and general attractiveness—is related to HTD. Other statistical research substantiates the common wisdom that high-technology manufacturing plants are likely to locate in large metropolitan areas with concentrations of scientific and technical manpower. Such analyses, however, are generally unable to reveal convincing relationships between HTD and many of the factors commonly thought to be important for location decisions of high-technology firms, such as proximity to a university or airport, cultural amenities, and business costs. This inability may result from the high level of aggregation in the available data, for both industries and metropolitan areas, as well as the complicated nature of the HTD process.

14. It is difficult to measure the effectiveness of State and local efforts to attract high-technology firms, due to inadequate data, the newness of the efforts, and the complex nature of HTD.

Many economists and analysts question whether these efforts have anything more than a marginal impact on HTD. Others see in the rush to HTD not only the risk of failure but also the danger of ignoring opportunities that are better suited to a region's needs and resources. The initiatives themselves are too varied and too recent to evaluate systematically, and their most important effects may be indirect and long term. However, the following factors seem to increase the chances for success:

- identifying and focusing on local needs and resources;
- adapting to external constraints;
- local initiative, leadership, and partnership;
- linkage with broader development efforts; and
- sustained effort, often for a period of decades.

In other words, HTD may be best served when States and cities emphasize: 1) strengthening links among financial, academic, and business communities; 2) improving the overall scientific and technological base of State and local economies; and 3) encouraging high-technology entrepreneurship and the creation of new firms. These are in fact the centerpieces of many programs. In addition, HTD programs may be more likely to benefit individual communities and the Nation as a whole if State and local efforts are supported or at least not hindered by policies and programs at the Federal level.

Implications for Federal Policy

The Federal Government already plays a significant role in regional HTD. Current Federal policies exert important influences on regional economies, and a wide range of existing Federal programs have made useful contributions to State and local HTD initiatives. However, OTA finds no compelling reason to launch an extensive new Federal effort to expand the Government's role. First, small changes in existing Federal programs could focus or enlarge their contributions to regional HTD, and in most cases the authority and mechanisms for doing so already exist. Second, changes in Federal policy with regard to taxes, R&D, technology transfer, and other national goals have also helped to create a more favorable climate for regional HTD over the past decade. Third, several other changes in Federal policy that have been proposed *to achieve broader national objectives* might also enhance the roles now played by the Federal Government in regional HTD.

Similarly, it might be desirable to establish a new mechanism to coordinate Federal efforts to promote technological innovation and industrial competitiveness. It might also be appropriate to make these efforts more responsive to, and supportive of, State and local HTD initiatives, which have already demonstrated their potential for promoting both technological innovation and regional economic development. But to organize a new institution solely around regional HTD, or to use regional HTD as the organizing principle for sweeping policy changes, would be to distort its relationship to larger national goals and objectives.

In short, it would seem most effective to continue the current Federal roles in regional HTD, and to sharpen those roles by including a regional perspective in the making of policy and the implementing of programs *for other purposes*--i.e., make innovation programs more regional, development programs more innovative, and macroeconomic policies more sensitive to both. This might best be pursued through incremental improvements in those roles *when it is possible to do so without sacrificing the original purpose of the policy or program involved.* This approach, however, imposes two important requirements:

- **better information** for policymaking and program implementation, particularly with regard to the impacts of current Federal programs and the effectiveness of various State and local mechanisms; and
- **improved coordination,** both among complementary Federal programs and between the Federal Government's efforts and those of various State and local groups, which may present an alternative to new Federal programs in this area.

Better Information

The most straightforward options for congressional action would be to continue those Federal programs that have provided indirect support for regional HTD, or have been used for these purposes by innovative local officials; to assess the potential contributions of other Federal programs; and perhaps to redirect agency efforts or reallocate funding to programs that can do so most effectively while still achieving their primary purposes. To pursue any of these options, however, will require better information than is currently available on the role of high-technology industry in regional economies and the impacts of Federal policy on regional economic change. Such information might take three general forms:

- **An information clearinghouse,** containing a comprehensive and up-to-date list of State and local initiatives, as well as Federal programs that have supported or influenced regional HTD—directly or indirectly—in ways similar to those identified by OTA. Periodic directories or online computerized data bases could be used, for example, but perhaps the most useful form would be similar to the "project bank" established by the White House Task Force on Private Sector Initiatives. This would provide potential users with information on what types of assistance are available, how they have been used by other communities, and what results can be expected from different combinations of programs in different regions.
- **Monitoring and evaluation of Federal programs,** both past and current, in order to identify those that have made (or might make) the most significant contributions to regional HTD. This would include, at the minimum, *retrospective evaluations of* the regional impacts of specific Federal programs, similar to those normally carried out by the General Accounting Office (GAO). In particular, the National Science Foundation (NSF) could be encouraged to evaluate and disseminate the results of its three "experiments" in regional HTD, described in chap-

ter 5. It might also include *ongoing evaluations* of the implementation and impacts of recent policy changes that may influence regional HTD. Both GAO and the Department of Commerce, for example, have recently released reports on the implementation of the Stevenson-Wydler Technology Innovation Act of 1980, although neither report directly addresses the impacts on regional HTD.

In addition, State and local governments would benefit significantly from *comparative analyses* of two specific types: the differential impacts of the Federal programs in different regions or situations; and the effectiveness and transferability of different types or combinations of HTD initiatives. Analyses of both types have been supported in the past by the Economic Development Administration's (EDA) Economic Research Division Development Administration in the Department of Commerce, although that office currently lacks the budget to publish a bibliography of its most recent research. NSF has recently solicited proposals for research on the effectiveness of State and local HTD initiatives, and should be encouraged to disseminate the results widely to State and local officials.

- **Statistical data** on the structure and dynamics of regional economies, which would be invaluable for monitoring economic changes and formulating economic policy at all levels of government. Such data are currently collected by the Bureau of the Census and Bureau of Labor Statistics, often on the basis of information supplied by the States. However, compilations and analyses of these data are not always available to State and local development officials on a timely basis or in a usable form. The results of the 1982 *Census of Manufactures*, for example, will not be available until 1986; the statistical analyses conducted for this assessment were based on data for 1972 and 1977. Similarly, *modeling and other econometric studies of regional economies*, concentrating on structural changes and the impacts of both technological change and public policies, would have immeasurable value for designing State and local economic development strategies. Several Federal Reserve Banks now maintain models of their region's economy and have made them available to local groups for planning purposes.

Providing these types of information would not require a new Federal institution. It would probably impose additional program costs in the form of new reporting requirements for executive agencies, and possibly on the recipients of Federal assistance. It would increase costs very little in most cases. It also has the advantage of familiarity—it would work through existing mechanisms, where lines of communication have already been established, participants are familiar with the procedures, and the costs and benefits of the programs are (or could be) fairly well determined. In addition, it would maintain the variety and resulting flexibility of the existing Federal roles in regional HTD, which appear to contribute to their usefulness. Finally, this option could be implemented quickly, in a number of different ways, and at a number of levels, some of which would require no change in legislation or appropriation.

Improved Coordination

Federal programs have had unsystematic and indirect but important impacts on regional HTD *when existing Federal programs are utilized in conjunction with a State or local HTD initiative.* Thus, it might be desirable to coordinate existing Federal programs that benefit regional HTD (in order to give them greater coherence) and to integrate Federal efforts with HTD initiatives at the local, State, or regional levels. This would increase efficiency by avoiding duplication and increasing leverage. It might also prove possible to implement Federal programs through mechanisms created by individual cities and States, or by several States with similar needs and opportunities.

Since most of these functions already exist, it would not be necessary to create a new Federal agency to carry them out. Several executive branch agencies, notably the Department of Commerce and the Small Business Administration (SBA), are already taking steps to coordinate their efforts with those of State and local governments. In other cases this could be accomplished, without new authority, through increased coordination between Federal agencies at the regional level. For example, there is a natural complementarity between the research activities of the EDA and those of the various Federal Reserve branches; similarly, much could be gained by coordinating the complementary activities of SBA (business development), Department of Housing and Urban Development (community and economic development), and the Departments of Labor and Education (Jobs Training Partnership Act, vocational education, and science and mathematics initiatives for human resource development). Alternatively, lead-agency responsibility could be assigned to an appropriate existing agency (e.g., Commerce, NSF).

Nor would the creation of a coordinating mechanism at the Federal level be required for regional HTD alone. If a mechanism is created for broader, related purposes, however, then it might be appropriate to give it this additional responsibility. For example, these functions could be assigned to an agency similar to or subordinate to any of the numerous mechanisms that have been proposed for purposes of formulating and implementing a national industrial policy—e.g., *regional* subcouncils, as opposed to (or in addition to) the *sectoral* subcouncils, foreseen for the proposed Council on Industrial Competitiveness (H.R. 4360 and 4362). This mechanism might also provide a central location for gathering and disseminating the types of information outlined above.

Another alternative would be the "federalization" of regional HTD through block grants or matching funds to States and communities to support their HTD initiatives. This option does not require the creation of new agencies or programs at the Federal level, and the assistance need not displace existing community development programs. It could be limited to planning grants and startup costs, or could include ongoing support for State technical extension services, seed capital mechanisms, and other initiatives. This alternative would maintain an explicitly experimental approach: it would recognize the many State and local HTD initiatives as a testing ground, and mandate an explicit Federal role in supporting, monitoring, evaluating, and disseminating information on successes and failures.

By supporting the creation of many initiatives at the State and local level, this alternative might lead to greater innovation, variety, and specificity than would be possible or appropriate at the Federal level. It would also protect against the consequences of a single, centrally determined policy or program design that turns out to be wrong-headed. The grants could be made on a competitive basis, allowing individual areas to design what they feel to be most needed or most effective for their economies. These grants would probably include a strong matching requirement to ensure both seriousness and prior networking on the part of recipients.

CHAPTER 2

Definition and Analysis of High-Technology Industries

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CHAPTER 2

Definition and Analysis of High-Technology Industry

Definitions of High-Technology Industry

Technological Innovation and Industrial Evolution

The lack of a generally accepted definition of "high-technology industries" complicates the investigation of the role these industries play in the economy and in national, State, and local development policies. To some, the term "high-technology" refers to a vague notion of industries involved with computers, telecommunications, electronics, biotechnology, and other emerging and rapidly evolving technologies.

Researchers have attempted to define such industries with greater precision by classifying them according to quantifiable criteria related to the industrial use of science and technology. Their job is complicated by the fact that high technology itself is constantly changing as innovations render earlier advances obsolete. Certainly, many technologies considered advanced 20 years ago—plastics or aerospace, for instance—have matured and are now considered standard. Moreover, the structure and needs of yesterday's high-technology industries are quite different from what they once were, and may also be different from those of the "new" high-technology industries.

Thus, the dynamic nature of the U.S. economy results from the birth, growth, maturation, and decline of various industrial sectors—and much of that change is the result of changes in the current state of high technology. Even if a uniform meaning were somehow assigned to the term, the factors that define high technology (and any policies designed to influence high-technology industries) must reflect the fact that industries and technologies evolve.

This industrial evolution, described by changes in what is considered high technology and what is considered standard, is driven by technological innovation, the process by which society generates and uses new products and manufacturing processes. This process consists of activities surrounding the generation, research, development, introduction, and diffusion of new or improved products, processes, and services for both public and private uses. What do we know about technological innovation?[1]

- Innovation is a complex process.
- Its essence is uncertainty about the outcome.
- Innovation can be costly and time-consuming.
- The economic and social impacts of innovations occur through their diffusion and widespread use.
- Basic scientific research seems to underlie technological change in complex and indirect, but important, ways.
- The innovation process differs from industry to industry.
- Financial and manpower resources are necessary, but not sufficient, for innovation.
- Both large and small firms play important roles in innovation, and those roles differ from industry to industry.
- Investment in industrial innovation activities responds, like other investments, to economic forces.

Since concepts of technological advance and innovation implicitly drive discussions of high-technology industry, quantifiable measures of innovative capacity or behavior are needed to facilitate analysis. Since the innovative behavior of firms and industries is very difficult to measure, two traditional measures of scientific activity are generally used as proxies to classify industries by innovative capacity or activity: 1) relative research and development (R&D) spending levels, usually as a percentage of sales; and 2) relative levels of scientific, engineering, and technical (SE&T) personnel in the industry's total work force. In addition, some researchers have separated out fast-growing industries or used measures of indirect R&D inputs.[2] These criteria are then used to rank industries, as defined by the Standard Industrial Classification (SIC) codes,[3] and lines are drawn to distinguish between those that, on average, spend a higher proportion of their resources on R&D and/or employ a higher proportion of technical workers.

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[1] Substance for most of these items can be found in Mary Ellen Mogee, "The Process of Technological Innovation in Industry: A State of Knowledge Review for the Congress," in Joint Economic Committee, U.S. Congress, *Study on Economic Change, Research and Development*, vol. 3, 1980. See also *Federal Support for R&D and Innovation*, Congressional Budget Office study, April 1984.

Definitions Used in This Assessment

Bureau of Labor Statistics (BLS).—A recent *Monthly Labor Review* article presented data on three groups of "high-technology" industries developed by BLS. These three definitions illustrate the differences that arise from applying different criteria, and they provide some bounds for the analysis that follows.[4]

- *Group 1.*—Industries in this group employ a proportion of technology-oriented workers greater than 1.5 times the average for all industries, or 5.1 percent of total employment. Industries with fewer than 25,000 employees were excluded, resulting in a list of 48 three-digit industries. Three out of four industries in this list are manufacturing industries.
- *Group 2.*—Industries in this group display ratios of R&D expenditures to sales greater than twice the average for all industries, or a minimum of 6.2 percent. Nonmanufacturing industries were excluded from this analytical cut due to data limitations. The resulting list included only six three-digit industries.
- *Group 3.*—Industries in this group had to satisfy criteria concerning both the relative R&D expenditures and the proportion of technology-oriented workers. In this case, the proportion of technology-oriented workers had to be greater than the average for all manufacturing industries (6.3 percent), and the R&D-to-sales ratio had to be close to or above the average for all industries (3.1 percent). In addition, some industries were excluded based on subjective evaluations of their major products, while two industries which provide technical services to manufacturing industries were added. This group includes 28 three-digit industries.

These three definitions (referred to hereafter as Groups 1, 2, and 3) incorporate the features most commonly used in establishing classifications of high-technology industries. Moreover, they provide a range of industry groupings within which most other definitions found in the literature will fit. The scope of Group 1, for example, is quite broad and represents over 12 million jobs, while Group 2 includes a very narrow range of industries and represents fewer than 3 million jobs. Group 3, the "moderate definition," represents about 6 million jobs. By comparison, total nonagricultural employment was almost 93 million in 1982, and employment in the manufacturing sector was about 22 million.

Group 3 corresponds closely to two other definitions used to investigate the structure and regional distribution of high-technology industry for this assessment. One, used by the Brookings Institution in conjunction with a Dun & Bradstreet data base, includes 96 four-digit SICs and represents slightly more jobs than Group 3.[5] The other, used by researchers at the University of California at Berkeley in conjunction with data from the Bureau of the Census, includes 99 four-digit SICs but represents slightly fewer jobs than Group 3.[6] These definitions are presented in table 1.

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[2] See, for example, Lester Davis, "New Definition of High-Tech Reveals That U.S. Competitiveness in This Area Has Been Declining," *Business America*, Oct. 18, 1982, pp. 18-23; and F. M. Schere. "Interindustry Technology Flows in the United States, *Research Policy* 11, 1982, pp. 227-245.

[3] SIC codes are used to classify business establishment by their types of business activities. Industries are divided into major groups, numbered 01 through 99. Each of these groups can be divided further, with each level of detail adding another digit to the code. For example, in the Manufacturing Division, Transportation Equipment is represented by SIC 37, Motor Vehicles and Motor Vehicle Equipment by SIC 371, and Truck Trailers by SIC 3715. These levels of disaggregation are referred to as the two-, three-, and four-digit SIC codes.

[4] Richard Riche, Daniel E. Hecker, and John U. Burgan, "High Technology Today and Tomorrow: A Small Slice of the Employment Pie," *Monthly Labor Review*, November 1983, pp. 50-58.

[5] Catherine Armington, Candee Harris, and Marjorie Odle, *Formation and Growth in High Technology Firms: A Regional Assessment* (Washington, DC: The Brookings Institution, under contract with OTA). The analysis and data were prepared for the National Science Foundation under grant No. ISI 8212970, with additional analysis prepared for OTA under an interagency agreement with the Small Business Administration. Original data development work was funded by SBA contract No. 2641-OA-79.

[6] Amy K. Glasmeier, Peter G. Hall, and Ann R. Markusen, *Recent Evidence on High-Technology Industries' Spatial Tendencies: A Preliminary Investigation*, University of California Institute for Urban and Regional Studies, under contract with OTA. The development of the data base and the majority of the descriptive analysis were done under contract with the National Science Foundation, contract No. SES 82-08104.

Table 1.—Five Definitions of High-Technology Industry

SIC	Industry	Bureau of Labor Statistics			Brookings	Berkeley
		1	2	3		
131	Crude petroleum and natural gas	X	—	—	X	—
1321	Natural gas liquids	—	—	X	—	—
162	Heavy construction, except highway and street	X	—	—	—	—
281	Industrial inorganic chemicals	—	—	X	X	X
282	Plastic materials and synthetics	X	—	X	X	X
283	Drugs	X	X	X	X	X
284	Soaps, cleaners, and toilet preparations	X	—	X	—	X
285	Paints and allied products	X	—	X	—	X
286	Industrial organic chemicals	X	—	X	X	X
287	Agricultural chemicals	X	—	X	—	X
289	Miscellaneous chemical products	X	—	X	X	X
291	Petroleum refining	X	—	X	X	X
301	Tires and inner tubes	X	—	—	—	—
3031	Reclaimed rubber	—	—	—	—	X
324	Cement, hydraulic	X	—	—	—	—
348	Ordnance and accessories	X	—	X	X	X
351	Engines and turbines	X	—	X	X	X
352	Farm and garden machinery	X	—	—	—	—
353	Construction, mining, and material handling machinery	X	—	—	X	X
354	Metalworking machinery	X	—	—	—	X
355	Special industry machinery, except metalworking	X	—	X	—	—
356	General industrial machinery	X	—	—	X	X
357	Office, computing and accounting machines	X	X	X	X	X
358	Refrigeration and service industry machinery	X	—	—	—	—
361	Electric transmission and distribution equipment	X	—	X	—	X
362	Electrical industrial apparatus	X	—	X	X	X
363	Household appliances	X	—	—	—	—
364	Electric lighting and wiring equipment	X	—	—	—	—
365	Radio and TV receiving equipment	X	—	X	X	X
366	Communication equipment	X	X	X	X	X
367	Electronic components and accessories	X	X	X	X	X
369	Miscellaneous electrical machinery	X	—	X	—	—
371	Motor vehicles and equipment	X	—	—	—	—
372	Aircraft and parts	X	X	X	X	X
3743	Railroad equipment	—	—	—	—	X
376	Guided missiles and space vehicles	X	X	X	X	X
381	Engineering, laboratory, scientific, and research instruments	X	—	X	X	X
382	Measuring and controlling instruments	X	—	X	X	X
383	Optical instruments and lenses	X	—	X	X	X
384	Surgical, medical, and dental instruments	X	—	X	X	X
3851	Ophthalmic goods	—	—	—	—	X
386	Photographic equipment and supplies	X	—	X	X	X
3872	Watches, clocks	—	—	—	X	—
483	Radio and TV broadcasting	X	—	—	—	—
489	Communication services, n.e.c.	X	—	—	—	—
491	Electric services	X	—	—	—	—
493	Combination electric, gas, and other utility services	X	—	—	—	—
506	Wholesale trade, electrical goods	X	—	—	—	—
508	Wholesale trade, machinery, equipment, and supplies	X	—	—	—	—
737	Computer and data processing services	X	—	X	X	—
7397	Commercial testing laboratories	—	—	—	X	—
7391	Research and development laboratories	X	—	X	X	—
891	Engineering, architectural, and surveying services	X	—	—	—	—
892	Noncommercial educational, scientific, and research organizations	X	—	—	X	—
	1980 employment total (millions)	12.6	2.5	6.2	6.7	4.8[a]

[a] 1977 data.

NOTE: The Berkeley and Brookings definitions do not include employment in all four-digit SIC codes included in the three-digit SIC codes listed.

SOURCE: *Monthly Labor Review*, November 1983; apps. B and C of this report.

Shortcomings of the Definitions

As discussed above, these definitions attempt to capture aspects of the technological innovation process. Although the measures employed—relative R&D spending or SE&T employment of industries—allow analysis, they are imperfect proxies, so the definitions are less than ideal. The definitions share several characteristics that affect their usefulness. Some of these are discussed here.

Standard Industrial Classifications.—The lists consist only of SIC codes, not individual firms or establishments. While the industries on the list share the relatively high reliance on R&D and SE&T workers, they are far from homogeneous. Moreover, the firms included in any particular SIC code can vary in size, structure, and other characteristics that influence their role in and their use of the technological innovation process. Furthermore, the criteria are applied to industry averages, not firms. Therefore, not every firm in each industry class on the list satisfies the criteria, although they are more likely to than firms in industries not on the list. The lists simply reflect groups of firms that, while sharing a common product and together satisfying certain criteria, can be quite different.

Product vs. Process Distinctions.—Second, since the SIC codes are product-oriented, the lists are too Within this framework, therefore, the narrower lists exclude some industries whose products are not considered high-technology, and do not spend a lot on R&D relative to their sales, but which may nevertheless rely heavily on high-technology processes or inputs. The agricultural and forestry industries, for example, rely heavily on new chemicals and innovative production techniques, yet are excluded from the lists. Similarly, the shoe and textile industries are modernizing their production processes with computer-aided design and manufacturing (CAD/CAM) equipment. To a large extent, however, these process improvements represent the outputs of other industries; developing a consistent list that includes both the producers and users of advanced-technology products and processes might require different criteria from those used for the producers and would pose some very difficult problems. Moreover, such lists would still suffer from aggregation problems similar to those discussed above—the firms within each SIC code are not homogeneous, and differences between firms' use of technology would be obscured.

Service Sector.—Another important definitional issue concerns recognition of a number of innovative or "high-technology" firms in the service sector. The production of computer software, for instance, is an innovative, high-growth, and technology-driven sector, yet it remains camouflaged in SIC 737, computer programming services. Perhaps parts of the software industry—like segments of the printing industry—would be more appropriately classified in the high-technology manufacturing sector. Further, the relationships between the service industries and other industries tend to be lost when classifying industries as above. To the extent that many service companies can be considered extensions of firms they support, their employment might be appropriately credited to the supported industries. What may appear as a small definitional issue thus may have important implications for comparing growth rates between the manufacturing and service sectors, and the producers and users of technology.

Size, Structure, and Growth of High-Technology Industry

The employment level in the so-called "high-technology" industries varies substantially depending on the definition chosen. Table 2 shows the degree of variability in size and growth for individual industries, while table 3 illustrates the effects of definitions by comparing the BLS groups to national employment levels. Table 3 shows that in 1982, of the 92 million wage and salary workers in the United States, 2.5 million were employed in the industries in Group 2, 5.7 million in Group 3, and 12.3 million in Group 1. Even the broadest definition (Group 1), which includes numerous nonmanufacturing industries, accounts for less than 14 percent of all wage and salary workers. While that percent-

Table 2.—Employment in High-Technology Industries, 1972, 1980, and 1982 (in thousands)

		High-technology group[a]			Employment			Percent change	
SIC	Industry	1	2	3	1972	1980	1982	1972-80	1972-82
131	Crude petroleum and natural gas	X			139.3	219.6	281.7	57.7	102.2
162	Heavy construction, except highway and street	X			495.1	658.5	633.9	33.0	28.1
281	Industrial inorganic chemicals	X		X	141.2	161.1	153.5	14.1	8.7
282	Plastic materials and synthetics	X		X	228.7	204.8	182.7	−10.0	−20.1
283	Drugs	X	X	X	159.2	196.1	199.8	23.2	25.5
284	Soaps, cleaners, and toilet preparations	X		X	122.4	140.9	245.3	15.1	18.7
285	Paints and allied products	X		X	68.6	65.1	59.7	−5.1	−13.0
286	Industrial organic chemicals	X		X	142.8	174.1	174.3	21.9	22.1
287	Agricultural chemicals	X		X	56.4	72.0	67.1	27.7	19.0
289	Miscellaneous chemical products	X		X	90.0	93.3	91.5	3.7	1.7
291	Petroleum refining	X		X	151.4	154.8	169.0	2.3	11.6
301	Tires and inner tubes	X			122.1	114.8	101.9	6.0	−16.5
324	Cement, hydraulic	X			31.9	30.9	28.5	−3.1	−10.6
348	Ordnance and accessories	X		X	81.9	63.4	71.4	−25.6	−12.8
351	Engines and turbines	X		X	114.6	135.2	114.8	18.0	0.2
352	Farm and garden machinery	X			135.0	169.1	130.8	25.3	−3.1
353	Construction, mining, and material handling machinery	X			293.7	389.3	340.9	32.6	16.1
354	Metalworking machinery	X			286.0	373.1	320.3	30.5	12.0
355	Special industry machinery, except metalworking	X		X	176.9	207.3	179.4	17.2	1.4
356	General industrial machinery	X			267.5	323.7	283.2	21.0	5.9
357	Office, computing and accounting machines	X	X	X	259.6	432.2	489.7	66.5	88.6
358	Refrigeration and service industry machinery	X			164.4	174.2	161.3	6.0	−1.9
361	Electric transmission and distribution equipment	X		X	128.4	122.5	110.1	−4.6	−14.2
362	Electrical industrial apparatus	X		X	209.3	239.9	211.8	14.6	1.2
363	Household appliances	X			186.9	163.2	142.0	−12.7	−25.0
364	Electric lighting and wiring equipment	X			204.4	209.2	186.9	2.4	−8.6
365	Radio and TV receiving equipment	X		X	139.5	108.8	94.6	−22.0	−32.2
366	Communication equipment	X	X	X	458.4	541.4	555.7	18.1	21.2
367	Electronic components and accessories	X	X	X	354.8	553.6	568.7	56.0	60.3
369	Miscellaneous electrical machinery	X		X	131.7	152.7	141.3	15.5	7.3
371	Motor vehicles and equipment	X			874.8	788.8	690.0	−9.8	−21.1
372	Aircraft and parts	X	X	X	494.9	652.3	611.8	31.8	23.6
376	Guided missiles and space vehicles	X	X	X	92.5	111.3	1127.3	20.3	37.5
381	Engineering, laboratory, scientific, and research instruments	X		X	64.5	76.8	75.7	19.1	17.4
382	Measuring and controlling instruments	X		X	159.6	245.3	244.3	53.7	53.1
383	Optical instruments and lenses	X		X	17.6	33.0	32.5	87.5	84.7
384	Surgical, medical, and dental instruments	X		X	90.5	155.5	160.4	71.8	77.2
386	Photographic equipment and supplies	X		X	117.1	134.6	138.3	15.0	18.1
483	Radio and TV broadcasting	X			142.7	199.6	216.4	39.9	51.6
489	Communication services, n.e.c.[b]	X			29.7	66.1	91.0	122.6	206.4
491	Electric services	X			312.0	391.0	415.1	25.3	33.0
493	Combination electric, gas, and other utility services	X			183.4	196.7	198.4	7.3	8.2
506	Wholesale trade, electrical goods	X			331.2	421.4	434.9	27.2	31.3
508	Wholesale trade, machinery, equipment, and supplies	X			868.6	1,307.7	1,344.9	50.6	54.8
737	Computer and data processing services	X		X	106.7	304.3	357.5	185.2	235.1
7391	Research and development laboratories	X		X	110.7	163.1	162.7	47.3	47.0
891	Engineering, architectural, and surveying services	X			339.3	544.9	568.7	60.1	67.6
892	Noncommercial educational, scientific, and research organizations	X			111.8	113.5	117.8	1.5	5.4

[a] *Group 1.* Includes industries with a proportion of technology-oriented workers (engineers, life and physical scientists, mathematical specialists, engineering and science technicians, and computer specialists) at least 1.5 times the average for all industries.

Group 2. Includes industries with a ratio of R&D expenditures to net sales at least twice the average for all industries.

Group 3. Includes manufacturing industries with a proportion of technology-oriented workers equal to or greater than the average for all manufacturing industries, and a ratio of R&D expenditures to sales close to or above the average for all industries. Two nonmanufacturing industries which provide technical support to high-technology manufacturing industries also are included.

[b] Not elsewhere classified.

SOURCE: *Monthly Labor Review*, November 1983.

Table 3.—Employment in Three Groups of High-Technology Industries, 1972, 1980, 1982 (in thousands)

Employment grouping	Employment			Percent change	
	1972	1980	1982	1972-80	1972-82
All wage and salary workers	76,547.0	92,611.2	91,950.1	21.0	20.1
Group 1	9,989.7	12,550.1	12,349.6	25.6	23.6
Percent of total employment	13.1	13.6	13.4	—	—
Group 2	1,819.4	2,486.9	2,543.0	36.7	39.8
Percent of total employment	2.4	2.7	2.8	—	—
Group 3	4,468.9	5,694.8	5,691.1	27.4	27.3
Percent of total employment	5.8	6.2	6.2	—	—

SOURCE: Bureau of Labor Statistics.

age is not insignificant, Group 1 includes many industry groups generally not considered producers of high-technology goods—heavy construction, motor vehicles, electric services, farm machinery, and wholesale trade in machinery and supplies, for example.

At the other extreme, Group 2 accounts for only 2.8 percent of the work force, but it excludes R&D laboratories, optical instruments, and many of the chemical-related industries. Finally, Group 3, falling between Groups 1 and 2, accounts for 6.2 percent of the work force. This definition is very similar to definitions commonly used by researchers and those on which much of the statistical analysis for this assessment was based.

These groups exclude some industries that might otherwise be considered high-technology, include some unexpected industries, and in general can be changed with minor modifications to the criteria. The distinction between high- and low-technology industries may also ignore the interdependence of these sectors.

In 1982, for example, U.S. business devoted one-half of its capital spending—some $56 billion in 1972 dollars to computers, instruments, electronics and communications equipment, up from one-third in 1977 and one-quarter in 1972.[7] Basic industry is an important customer for the products and processes developed and marketed by the so-called high-technology industries. Indeed, a steel plant that invests in advanced process technologies, modern instrumentation and control systems, and state-of-the-art materials-handling equipment is a high-technology undertaking. Some of the differences between high-technology industries and others may be worth noting, however—the size of firms and the employment growth rates, in particular.[8]

Firm Size

High-technology industries are composed of firms that are on average larger, and rely more on branch facilities, than those in low-technology manufacturing and service industries.[9] Analysis by the Brookings Institution shows that such establishments employ an average of 69 employees, while those in low-technology manufacturing and service industries employ an average of 32, and those in other industries, an average of 13. Eighty-eight percent of employment in the high-technology industries is found in firms with more than 100 employees. By contrast, 72 percent of employment in low-technology manufacturing and service industries and 58 percent in other industries is found in these larger firms. Further, compared with 60 percent of all private jobs, 88 percent of employment in the high-technology industries is found in multiestablishment firms. Finally, while about one-third of jobs in low-technology manufacturing and service industries are found in firms' out-of-State affiliates, such affiliates provide half of the jobs in the high-technology industries.[10]

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[7] "Shackles on Growth in the Eighties," *Fortune*, Oct. 4, 1982.

[8] Unless otherwise noted, data in this chapter concerning the structure and location patterns of high-technology industries come from the work of Armington, Odle, and Harris, at the Brookings Institution and Glasmeier, Markusen, and Hall, at University of California-Berkeley.

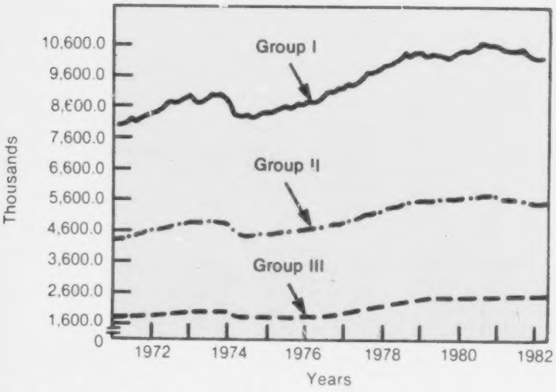
[9] "Low-technology manufacturing and service industries" are those manufacturing and service industries that do not satisfy the criteria for inclusion in the "high-technology" list. "Other industries" refers to those not considered manufacturing or service industries, such as agriculture, construction, wholesale and retail trade, and some mining, for example.

[10] Armington, et al., op. cit.

Employment Growth Rates

Another difference between these industries concerns employment growth rates. Regardless of which of the three BLS definitions is considered, the aggregate employment growth rates of these groups were higher than that of total wage and salary employment during the periods 1972-80 and 1972-82 (see table 3). Like that in most other industries, the growth in the listed industries was neither continuous nor steady. Some of the industries included in the listings had cyclical employment losses, especially apparent during the 1974-75 recession. Because the industries are a relatively small percentage of total employment, the magnitude of changes is also relatively small. For example, during that period, employment in Group 2 and Group 3 industries fell by only about 200,000 and 500,000 respectively. Figure 1 shows the employment trends of each group of industries from 1972 to 1982.

Figure 1.—Employment in High-Technology Industries, 1972-83



SOURCE: Bureau of Labor Statistics.

High-Technology Employment Projections

Although high-technology industries grew, in the aggregate, faster than other groups of industries, they will probably provide approximately the same proportion of jobs in the future. Projecting future employment trends is beyond the scope of OTA's assessment. An overriding difficulty comes from a basic inability to see job types and industries that simply do not exist yet. Complicating this is uncertainty about the impact of automation on employment in basic industries and the ability of high-technology industries to provide jobs for displaced blue-collar workers. Also unknown is how many jobs will go to lower cost labor markets in foreign countries as high-technology production gears up.

Although projections are fraught with uncertainty, the Department of Labor's Bureau of Labor Statistics prepares employment projections of roughly 12 years. The latest BLS projections of moderate, high, and low growth extend through 1995. For each of the three groups defined previously and using either 1980 or 1982 as a base, high-technology employment is projected to grow somewhat faster than total wage and salary under all three growth alternatives. As table 4 shows, the size of the total pool of wage and salary workers is projected to grow by between 26 and 31 percent between 1982 and 1995, depending on economic conditions projected. Although employment in the high-technology industries is projected to grow by between 32 and 39 percent, depending on scenario and definition, the proportion of the work force in the industries remains small.[11]

Geographical Patterns of High-Technology Industry Location

Although a few regions maintain a reputation for large concentrations of high-technology industries, these industries have been dispersing throughout the Nation, along with the population and other manufacturing activity. This spreading of high-technology industries holds promise for areas that have not

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[11] For Group 2, the low growth alternatives shows higher 1995 employment than the moderate alternative. This is because higher defense spending is assumed in the low alternative than in the moderate alternative, and Group 2 has a high proportion of its employment in three defense-related industries; communications equipment, aircraft and parts, and guided missiles and space vehicles.

Table 4.—Employment in Three Groups of High-Technology Industries, 1972, 1980, 1982 and Projected 1995 (in thousands)

	Employment			Projected 1995 employment alternatives			Percent change					
							1980-95			1982-95		
Employment grouping	1972	1980	1982	Low	Moderate	High	Low	Moderate	High	Low	Moderate	High
All wage and salary workers	76,547.0	92,611.2	91,950.1	115,382.9	117,744.9	120,531.1	24.6	27.1	30.1	25.5	28.1	31.1
Group 1	9,989.7	12,550.1	12,349.6	16,260.7	16.612.9	16,931.6	29.6	32.4	34.9	31.7	34.5	37.1
Percent of total employment	13.1	13.6	13.4	14.1	14.1	14.0	—	—	—	—	—	—
Group 2	1,819.4	2,486.9	2,543.0	3,517.5	3,409.6	3,452.9	41.4	37.1	38.8	38.3	34.1	35.8
Percent of total employment	2.4	2.7	2.8	3.0	2.9	2.9	—	—	—	—	—	—
Group 3	4,468.9	5,694.8	5,691.1	7,746.6	7,719.8	7,890.0	36.0	35.6	38.5	36.1	35.6	38.6
Percent of total employment	5.8	6.2	6.2	6.7	6.6	6.5	—	—	—	—	—	—

SOURCE: Bureau of Labor Statistics.

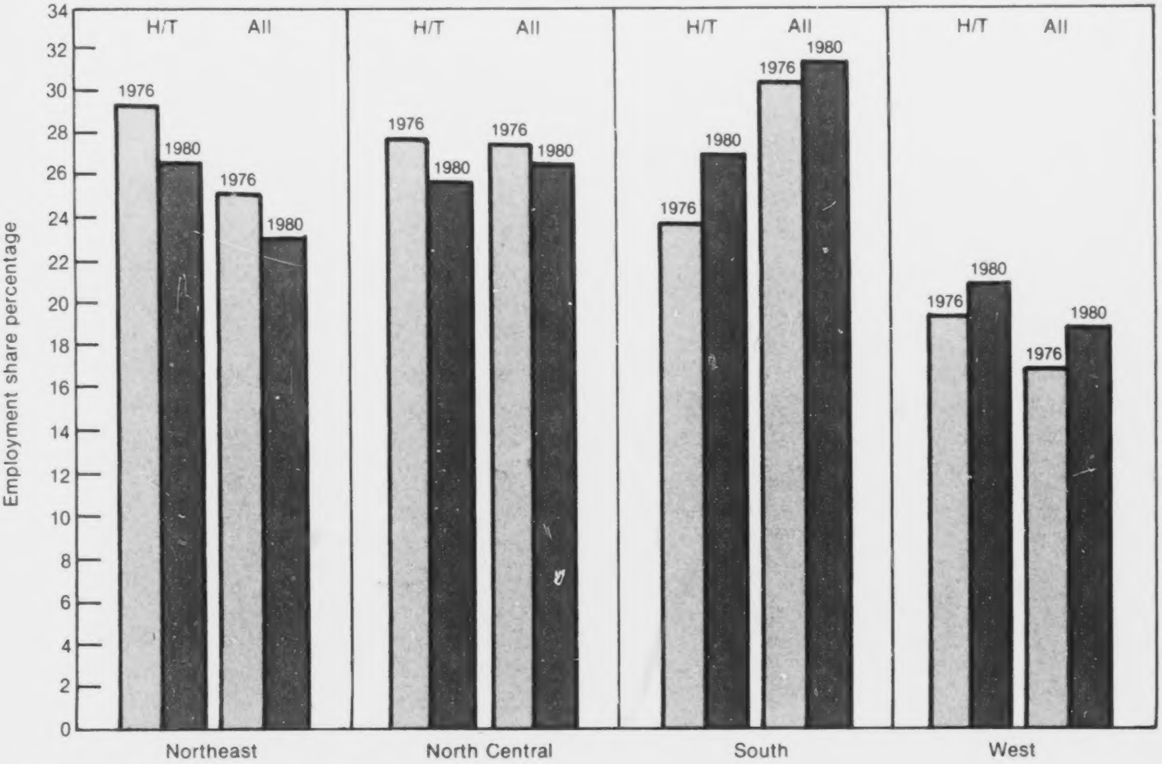
previously benefited from HTD. Researchers at University of California-Berkeley have found that while some high-technology industries contracted during the 1970's, most often became more dispersed. On average, they appeared in 18 percent more counties in 1977 than in 1972.

Regions.—Analysis by the Brookings Institution reveals that the regional distribution of high-technology industry employment roughly parallels that of total nonagricultural employment. The Northeast and perhaps the West have higher proportions of high-technology employment, and the South a lower one, relative to the distribution of total employment (fig. 2). Further, more than two-thirds of the high-technology employment in the South is found in branches of out-of-State firms, while the other regions average less than half. Of the four regions, however, the South also had the highest net rate of employment growth in these industries; the West had the second highest rate of employment growth, followed by the North Central and the Northeast.

In general, the trend indicates a convergence of the regional shares of high-technology employment. Further, in all regions, employment growth from the creation of new establishments and the expansion of existing businesses was higher for high-technology industries than for other industries (table 5). These regions are quite broad, however, and within them, the distribution and growth patterns of high-technology industries can vary greatly.

States.—Once again, definitional issues complicate analysis of the distribution of these industries. First, the definition affects the rankings because individual industries are not evenly distributed: a State with a large concentration of a particular industry would be affected by whether that industry is in-

Figure 2.—Regional Shares of High-Technology (H/T) Employment and All Industry Employment 1976, 1980



SOURCE: Office of Technology Assessment with Brookings Institution data.

Table 5.—Employment Change by Type and Region for High- and Low-Technology Manufacturing and Business Services as a Percent of 1976 Employment Within Region and Sector, 1976-80

	Net	Formations	Expansions	Contractions	Closures
U.S. Total:					
High	19.4%	23.8%	24.6%	−11.3%	−17.8%
Low	11.7	19.0	21.0	−10.5	−17.7
Northeast:					
High	7.5	16.3	21.3	−13.7	−16.4
Low	4.3	14.2	18.9	−11.6	−17.2
North Central:					
High	12.5	19.6	19.2	−10.4	−15.9
Low	8.5	16.3	18.6	−10.5	−15.8
South:					
High	34.1	34.2	27.9	−9.6	−18.5
Low	15.8	22.5	22.3	−10.0	−19.0
West:					
High	29.3	28.4	33.5	−10.9	−21.7
Low	25.0	26.8	27.8	−9.6	−20.0

SOURCE: The Brookings Institution.

cluded.[12] Rankings also vary according to the choice of absolute or relative levels of high-technology employment. Using the BLS Group 3 definition, for example, the 10 States with the highest number of workers in high-technology industry in 1982 accounted for 60 percent of all high-technology employment; the top five States accounted for 41 percent, a percentage that has remained fairly level since 1975 (table 6).[13]

The list of States with the *highest percentage of workers employed in high-technology industries*, however, is dramatically different. Table 7 shows that high-technology industries represent a high percentage of the Delaware work force under Groups 1 and 3, which include the chemical industry, but not under Group 2. California, on the other hand, ranks not higher than fifth under even the narrowest list. In general, the top 10 States are dominated by the New England region, where high-technology industries hold a large share of a proportionately large manufacturing sector.

Metropolitan Areas.—Just as the national and regional data hide some patterns apparent at the State level, high-technology concentrations can vary within States and may have a major impact on local economies, even in a State not dominated by high-technology industries. Analysis by University of California-Berkeley researchers shows that the percentage of an area's labor force employed in high-technology industries in 1977 varied from almost 20 percent to less than 0.05 percent for the 277 Standard Metropolitan Statistical Areas (SMSAs), with a median of 4.4 percent. Table 8 lists the SMSAs with the highest and lowest ratios for 1977. Only one of the top 10 SMSAs—San Jose, in the heart of California's Silicon Valley, is in a top 10 State under the comparable BLS Group 3 definition. A high ratio of high-technology employment is not, however, a guarantee of prosperity: of the 50 SMSAs with the highest ratios in 1977, 12 had high-technology employment losses during the period 1972-77.[14]

Although the evidence points to growth of high-technology industries throughout the country, recent data from the BLS indicates that most high-technology employment remains in the largest metropolitan areas. In California, Texas, and Michigan, for example, 91 percent, 75 percent, and 79 percent, respectively, of the high-technology jobs are found in the each State's five largest SMSAs. In general, this trend is similar to that found for all manufacturing, 64 to 74 percent of which is located in metropolitan areas.[15]

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[12] For example, Ohio and Illinois fall within the top five States in high-technology employment, if the BLS Group 1 definition (the broadest definition, accounting for 14 million jobs) were used. This can probably be attributed to the inclusion of motor vehicle and industrial machinery industries, among others. If those industries are excluded under the more restrictive Group 3 definition (accounting for about 6 million jobs), Illinois drops to seventh place and Ohio falls out of the top 10. See Riche, et al., op. cit.

[13] Riche, et al., op. cit., p. 57.

[14] Glasmeier, et al., op. cit.

[15] Riche, et al., op. cit., p. 56.

Table 6.—Employment in Three Groups of High-Technology Industries in 10 States With Highest Levels of High-Technology Employment, 1982 Annual Averages (in thousands)

Group 1		Group 2		Group 3	
Total United States	13,038.3	Total United States	2,633.7	Total United States	5,943.4
Top 10 States	7,489.5	Top 10 States	1,737.4	Top 10 States	3,566.6
California	1,527.5	California	610.6	California	933.1
Texas	1,068.4	New York	205.3	New York	493.4
New York	924.0	Massachusetts	160.7	Texas	372.0
Ohio	683.0	Texas	157.6	New Jersey	316.8
Illinois	672.0	New Jersey	116.9	Massachusetts	305.5
Michigan	651.0	Florida	108.1	Pennsylvania	277.0
Pennsylvania	615.4	Connecticut	98.5	Illinois	261.5
New Jersey	521.7	Illinois	96.2	Ohio	247.8
Massachusetts	450.0	Pennsylvania	93.3	Connecticut	185.8
Florida	376.5	Washington	90.2	Florida	173.7
Share		Share		Share	
Top 10	57.4%	Top 10	66.0%	Top 10	60.0%
Top 5	37.4	Top 5	47.5	Top 5	40.7

[a]Because fourth-quarter 1982 data were not available at the time of publication, a 9-month average was used.

SOURCE: Bureau of Labor Statistics.

Table 7.—High-Technology Employment as a Percent of Total Nonagricultural Employment in Top 10 States Under Three Definitions, 1982 Annual Average[a]

Group 1		Group 2		Group 3	
Total United States	13.4	Total United States	2.8	Total United States	6.2
Delaware	24.0	New Hampshire	7.2	Delaware	16.2
New Hampshire	21.0	Vermont	7.0	Connecticut	13.0
Michigan	20.4	Connecticut	6.9	New Hampshire	12.5
Connecticut	20.3	Arizona	6.8	Vermont	11.7
Vermont	18.9	California	6.2	Massachusetts	11.7
Indiana	17.6	Massachusetts	6.1	New Jersey	10.3
Massachussetts	17.2	Washington	5.7	California	9.5
Texas	17.0	Kansas	4.7	Arizona	9.0
New Jersey	16.9	Utah	4.2	Washington	8.2
Kansas	16.5	Colorado	3.9	Kansas	7.8
Ohio	16.5				

[a]9-month average.

SOURCE: Bureau of Labor Statistics.

Table 8.—SMSAs With the Highest and Lowest Percentage of Employment in High-Technology Industries, 1977

Highest percentage		Lowest percentage	
Rockford, IL	19.6	Killeen, TX	a
Melbourne-Titusville, FL	18.0	Columbia, MO	a
Wichita, KS	17.7	Grand Forks, ND-MN	a
San Jose, CA	17.4	Pueblo, CO	0.1
Binghamton, NY	15.2	Anchorage, AK	0.1
Lake Charles, LA	14.6	Clarksville, TN-KY	0.2
Cedar Rapids, IA	14.6	Honolulu, HI	0.2
Bloomington, IN	12.9	Great Falls, MT	0.3
Johnson City, TN-WV	12.8	McAllen Pharr, TX	0.4
Longview, TX	12.7	Laredo, TX	0.4
	Median—4.4		

[a]= less than 0.1 percent.

SOURCE: Glasmeier, et al.

Factors Influencing Patterns of High-Technology Industry Location

Some aspects of traditional business location theories can be applied to the location decisions of high-technology industries, but statistical evidence is sketchy. Firms and industries choose to locate in certain areas for a variety of complex reasons. Regional economic lifecycle theories suggest that each community has different needs and can offer different resources to firms. Similarly, each industry and every firm requires its own mix of resources from its location, and offers its unique mix of benefits and impacts. Moreover, these needs and impacts change as firms, industries, and communities evolve.[16]

In general, factors affecting location of businesses have been separated into two types: 1) those relating to the costs of moving materials, products, people, and ideas; and 2) those relating to the attributes of areas. Traditionally, with industries relying on large quantities of bulky raw materials, or the transportation of heavy products, the transportation costs weighed heavily. To the extent that the high-technology industries are different from basic industries—in that they rely less on heavy raw materials and produce goods that are costly relative to their weight—their bulk transportation needs may be considered less important than the need to attract and transport people. Similarly, there may be some distinctions in the need for skilled or unskilled labor, energy use, ability to pay taxes, or in any of the other traditional location factors.

The results of two surveys that point to these differences and the complex nature of location decisions are shown in table 9. The first part of the table shows that the factors considered important by high-technology and non-high-technology plants are similar, although perhaps weighted differently. The second part of the table indicates that the search for a high-technology plant location really consists of two searches—first for a broad region, then for a site within the region—and that the factors may vary between stages. Moreover, not only can the factors influencing location decisions vary by the kind of firm and the stage of the site selection process, but they also depend on the type of facility, and whether the facility is an expansion or relocation of an existing firm or a new business formation.[17] Accurate generalizations about the factors that influence the location of high-technology firms and facilities are clearly difficult to make.

Statistical evidence to document the relationships between characteristics of communities and high-technology development from sources other than surveys remains quite sketchy. The Brookings and Berkeley studies show that, although data limitations and aggregation problems plague such analysis, statistical analysis can reveal some relationships.[18] For the most part, however, the correlations were weak. Brookings tested 13 independent variables against business formations and employment growth for both high- and low-technology industries in a sample of 35 SMSAs for the period 1976-80. Berkeley tested 19 independent variables in 219 SMSAs against three measures of HTD for the period 1972-77: ratio of high-technology to total employment, change in high-technology employment, and change in the number of high-technology plants.

In general, these analyses "explained" differences in high-technology *formations* (new establishments) better than differences in high-technology *dependence* (share of local employment) or high-technology *employment growth*. None of these patterns was explained very well, however, and the resulting correlations cannot be considered statistically strong. Data aggregation problems hindered the analysis, but the lack of clear results also points to the complicated nature of industrial location decisions. Correlations from available data indicate that the following community characteristics are significantly associated with HTD:

- *Population growth during the previous 5 years*, an indicator of general attractiveness and growth potential, had a strong relationship to formations and employment growth in both the high- and low-technology manufacturing sectors.

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[16] John Rees and Howard Stafford, *High-Technology Location and Regional Development: The Theoretical Base*, OTA contractor paper, May 1983.

[17] Ibid.

[18] Armington, et al., op. cit.; and Glassmeier, et al., op. cit.

Table 9.—Location Factors Influencing New Manufacturing Plants

High-technology and non-high-technology plants

Rank	High-technology plants	Non-high-technology plants
1	Labor	Labor
2	Transportation availability	Market access
3	Quality of life	Transportation availability
4	Markets access	Materials access
5	Utilities	Utilities
6	Site characteristics	Regulatory practice
7	Community characteristics	Quality of life
8	Business climate	Business climate
9	Taxes	Site characteristics
10	Development organizations	Taxes

SOURCE: H. A. Stafford, Survey of 104 Plants, 1983.

High-technology plants

Rank	Selection of region	Selection within region
1	Labor skills/availability	Labor availability
2	Labor costs	State/local tax structure
3	Tax climate within region	Business climate
4	Academic institutions	Cost of property/construction
5	Cost of living	Transport availability for people
6	Transportation	Ample area for expansion
7	Markets access	Proximity to good schools
8	Regional regulatory practices	Proximity to amenities
9	Energy costs/availability	Transport facilities for goods
10	Cultural amenities	Proximity to customers

SOURCE: Joint Economic Committee, U.S. Congress, *Location of High Technology Firms and Regional Economic Development*, June 1, 1982, tables III.5 and 6, pp. 23 and 25.

- *Proportion of the labor force in technical occupations* was strongly related to high-technology formations and even more strongly to formations of tiny *high-technology establishments* (a statistical proxy for new spinoff and startup firms), but not to low-technology manufacturing or other formations. *Larger city sizes* and *larger labor forces* appear to be correlated high- and low-technology formations alike.

High rates of population growth probably represent an amalgam of characteristics that seem to make an area attractive for migration of people and businesses in general. The higher percentage of technical workers in an area could represent a variety of situations, from an existing concentration of facilities employing such workers to influences of colleges or universities. Other evidence suggests that higher per-capita levels of Federal defense spending go hand in hand with high-technology industries. This may simply reflect the fact that the definitions of high-technology industry tend to be weighted by defense-oriented industries.

Only more disaggregated regional and industrial data would allow more convincing statistical evidence of the relationship between specific community characteristics and high-technology development. Whether such analysis would ever really be convincing, however, remains unclear, because of the complex nature of both economic development and multifaceted characteristics of technology-based industry. In addition, even when correlations between certain factors and high-technology development are revealed, establishing causal relationships is very difficult. Finally, since the available data are dominated by large, multiestablishment firms, analysis of high-technology location patterns focus implicitly on factors that influence the location of branch facilities. The patterns and factors for the creation of *new* firms may be slightly different, but they are overwhelmed by data on the branching of *existing* firms.

CHAPTER 3

The Roles of Entrepreneurship and Venture Capital in High-Technology Development

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CHAPTER 3

The Roles of Entrepreneurship and Venture Capital in High-Technology Development

Introduction

What role is played by *new* high-technology firms? What are the conditions that lead to their creation and survival? The large, expanding firms whose branch plants appear to drive so much of high-technology development (HTD) were once small and young, after all, and the success of California's Silicon Valley and Massachusetts' Route 128 are based in part on their role as "seedbeds" for these new startups. In addition, research indicates that small, new firms play an important role in the processes of technological innovation, new product development, and job creation.[1]

This chapter begins with an examination of existing high-technology centers and the theoretical explanations for these geographic concentrations of innovative activity. The combination of conditions that make them so productive of new technologies and new firms constitutes what has variously been called the "technological infrastructure," "agglomeration effect," or "entrepreneurial network." There follows a general consideration of entrepreneurship, the role it plays in the creation of new high-technology firms, and the reasons it flourishes in existing centers of HTD. One of the most important reasons may be a relative abundance of venture capital in those regions. Thus, the chapter concludes with an examination of the special role of venture capital in high-technology entrepreneurship, the growth and structure of the venture capital industry, and recent trends in the availability of venture capital in different regions.

High-Technology Complexes

Overview

Certain regions appear to offer a more promising environment for new technology-based businesses than others. The patterns identified by recent research suggest, for example, that while high-technology growth in the South is dominated by the formation of new branches by multistate firms, growth in the Northeast and West is driven by the formation of independent firms and local branches.[2] The economic theories reviewed in chapter 2 suggest that this results from a "regional economic development lifecycle." That is, the initial concentration of high-technology firms reaches a self-sustaining "critical mass," at which time sufficient external economies develop to ensure the further growth of HTD.

Research on the origins and growth of existing high-technology complexes—the "archetypes" of Silicon Valley and Route 128—suggests that these HTD success stories are essentially spontaneous and idiosyncratic.[3] That is, their emergence was caused by the fortuitous confluence of *technological opportunity*, created by fundamental advances in microelectronics that opened up a wide range of innovations and potential applications, with the *preexisting socioeconomic conditions* in each region. In both cases, furthermore, a critical catalytic role was played by a particular person, firm, or institution. The result was cumulative, leading to *agglomeration economies* that tended to enhance the region's resources and encourge high-technology entrepreneurship. In both of these regions, growth was driven by local startups and spinoffs from firms already in the area.

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[1] See for example Louis G. Tornatzky, et al., *The Process of Technological Innovation: Reviewing the Literature* (Washington, DC: National Science Foundation, May 1983).

[2] Catherine Armington, Candee Harris, and Marjorie Odle, *Formation and Growth in High Technology Firms: A Regional Assessment* (The Brookings Institution, Washington, DC, under contract with OTA). The analysis and data were prepared for the National Science Foundation under grant No. ISI 8212970 with additional analysis prepared for OTA under an interagency agreement with the Small Business Administration. Original data development work was funded by SBA contract No. 2641-OA-79.

[3] Histories and comparative analyses of Silicon Valley and Route 128 can be found in the following sources: Peter J. Brennan, "Advanced Technology Center, Santa Clara Valley, California," *Scientific American*, vol. 244, No. 3, March 1981, pp. SC-1-10; Nancy S. Dorfman, "Route 128: The Development of a Regional High Technology Center," *Research Policy*, vol. 12, 1983, pp. 299-316; see also her *Massachusetts' High Technology Boom in Perspective: An Investigation of Its Dimensions, Causes and the Role of New Firms*, CPA 82-2 (Cam-

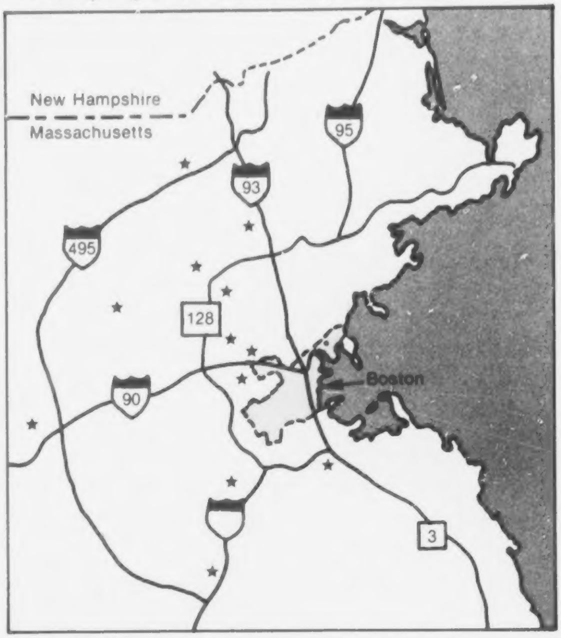
Many of these conditions cannot be replicated elsewhere, at least in electronics, because the regions that have already developed such complexes provide a comparative advantage in the creation of advanced products and new high-technology firms. Some of the conditions can be replicated, however, particularly those involving components of the *technological infrastructure* such as informal communication networks and institutional cooperation. In addition, the negative impacts of increasing concentration, combined with the maturation of the technologies themselves, have led to the dispersion of these boom industries out of their original seedbeds. This creates opportunities for additional communities to attract production facilities, on which a local scientific and technical base can be built. Furthermore, similar opportunities are being opened by advances in other technologies, such as robotics and biotechnology. Finally, the applications of new products and manufacturing technologies also create new opportunities for declining industries and the regions in which they are concentrated.

Technological Infrastructure and Agglomeration

The various resources—scientific, financial, human, and institutional—on which HTD depends constitute the region's *technological infrastructure*. Of interest to the present investigation are the following:

- applied research and product development activities at nearby universities, Federal laboratories, and existing firms;
- informal communication networks that provide access to information and technology transfer from those research and development (R&D) activities;
- scientific and technical labor force, including skilled craftsmen, newly trained engineers, and experienced professionals (who also represent a pool of potential entrepreneurs);
- a network of consultants (often augmented by university faculties) specializing in hardware, software, business development, and venture capital;
- a network of job shoppers and other suppliers of specialized components, subassemblies, and accessories; and
- proximity to complementary and competitive enterprises, as well as distributors and customers.

A Sampling of Route 128 High-Technology Firms



★ —Location of some of the high-technology firms in the area.

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bridge, MA: Center for Policy Alternatives, Massachusetts Institute of Technology, 1982); Robert Premus, *Location of High Technology Firms and Regional Economic Development*, staff study prepared for the Subcommittee on Monetary and Fiscal Policy, Joint Economic Committee, serial 94-670 O (Washington, DC: U.S. Government Printing Office, June 1, 1982), app. A; and AnnaLee Saxenian, *Silicon Valley: Regional Prototype or Historical Exception?* paper presented at the Conference on Microelectronics in Transition: Industrial Transformation and Social Change, University of California at Santa Cruz, May 1983.

R&D activities appear to be particularly important, and industrial R&D tends to be concentrated in a few major urban areas specializing in particular technological applications. This gives an advantage to firms in those regions developing related innovations, because of both technology transfer and the demand for their products from existing firms. Research at universities and Federal laboratories exerts a decentralizing influence on the geographic location of R&D.[4] This influence varies among industries, and appears to be greatest in biomedical, computer, and energy R&D. In the past, university and Federal R&D has not resulted in significant agglomeration if industrial R&D was not also present, but there is evidence that industrial R&D is also becoming less concentrated. The most common sites for decentralized R&D are production installations, and chapter 2 has shown that these branch plants are also becoming more dispersed.

The resources provided by the technological infrastructure are particularly advantageous in high-technology complexes, which are largely made up of small, specialized companies that often depend on other firms for supplies, services, and markets. Concentration of these resources in one area enhances their productivity by creating *external economies of scale,* in both production and marketing, similar to the internal economies created by the size and vertical integration of much larger corporations. This *agglomeration* of new firms attracts and retains skilled professionals in the region, promotes informal communication among them, strengthens and diversifies the technological infrastructure, and draws venture capital to the region by creating opportunities for profitable investment.[5]

Agglomeration also places entrepreneurs at the center of competitive turmoil, where they are able to identify new market niches and have the incentive to fill them quickly. In addition, the agglomeration appears to encourage entrepreneurial activity, both by providing local role models and by providing a supportive environment that reduces risk and uncertainty, either actually or subjectively. As a result of this "network of mutual dependency," an industry undergoing rapid technological development can be expected to show "a tendency . . . to grow faster in a region the greater the degree of agglomeration there, other things being equal."[6]

Other evidence underscores the importance of the "threshold" phenomenon of the agglomeration model. A recent study of the formation of new and small technology-based firms since 1975 reveals that the principal determinant of the geographic distribution of these firms is the presence of similar firms and the presence of major research universities and independent research institutes. The strong positive correlation between new and older firms indicates that, if the economic conditions in a region are favorable to existing high-technology firms, they are likely to be advantageous for new firms as well.[7]

Small Firms and Innovation

In addition, a large body of research indicates that small, new firms play an important role in the processes of technological innovation, new product development, and job creation. In general, the rate of innovation within organizations is positively correlated with its size; larger firms may have greater innovative potential since they can operate larger R&D departments and bring greater resources to bear upon problems.[8] This generalization may not hold for high-technology firms, however. Some researchers claim a superior innovative potential of small firms because they are more vigorous and respond more quickly than larger firms to new ideas and market conditions.[9] This is most likely to be the case in agglomerations, for the reasons outlined above; it is because of their responsiveness to market opportunities that existing high-technology complexes have been such prolific "incubators" of new firms and products.

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[4] Edward J. Malecki, "Science, Technology, and Regional Economic Development: Review and Prospects," *Research Policy,* vol. 10, 1981, pp. 312- 334; see also Irwin Feller, "Invention, Diffusion and Industrial Location," in *Locational Dynamics of Manufacturing Activity,* L. Collins and D. F. Walker (eds.) (New York: Wiley, 1975), pp. 83-107.

[5] Dorfman, op. cit., p. 308.

[6] Ibid., p. 307.

[7] Stephen G. Graham, *The Determinants of the Geographical Distribution of the Formation of New and Small Technology-Based Firms,* doctoral dissertation, Department of Finance and Insurance, Michigan State University, 1981.

[8] Everett M. Rogers, *Diffusion of Innovations,* 3d ed. (New York: Free Press, 1983); Joseph Schumpeter, *Capitalism, Socialism, and Democracy,* 2d ed. (New York: Harper & Row, 1942); John Kenneth Galbraith, *The New Industrial State,* 3d ed. (Boston: Houghton Mifflin, 1967).

[9] Kenneth J. Arrow, "Innovation in Large and Small Firms," in *Entrepreneurship,* Joshua Ronen (ed.) (Lexington, MA: Lexington Books, 1983), pp. 15-28; *Small Businesses Are More Active as Inventors Than as Innovators in the Innovation Process,* PAD-82-19 (Washington, DC: U.S. General Accounting Office, 1981); Lynn Bollinger, Katherine Hope, and James M. Utterback, "A Review of Literature and Hypotheses on New Technology based Firms," *Research Policy,* vol. 12, pp. 1-14; Pierre-Andre Julien and Christian Lafrance, "Towards the Formalization of 'Small is Beautiful': Societal Effectiveness Versus Economic Efficiency," *Futures,* June 1983, pp. 211-221; James Brian Quinn,

Other research suggests that firm size may not be a decisive factor in innovation, and indeed that a variety of sizes—from very small to very large, like that found in the agglomerations described above—may be a key to continued innovation in an industry and growth in a region.[10] Because innovative activity is "inherently untidy," this variety within an industry or region hedges against the possibility that opportunities for innovation will be ignored by a set of overly homogeneous firms.[11] In addition, many high-technology firms do not survive, and even successful firms have shown a tendency to locate their production operations in areas outside the original seedbed. As a result, the continued creation of spinoffs and other new starts will be necessary to sustain the process of innovation and regional HTD.

Outlook for Other Regions

The above discussion, and the experience of existing high-technology complexes, make clear the importance of entrepreneurship and startups in technological innovation and regional HTD. Many of the conditions that led to these agglomerations cannot be replicated elsewhere, at least in the particular areas of microelectronics—merchant semiconductors and microcomputers—in which Silicon Valley and Route 128 specialize. Because of their self-sustaining concentration of complementary businesses, these regions provide a comparative advantage in the creation of advanced products and new high-technology firms *in these high-technology sectors.*[12]

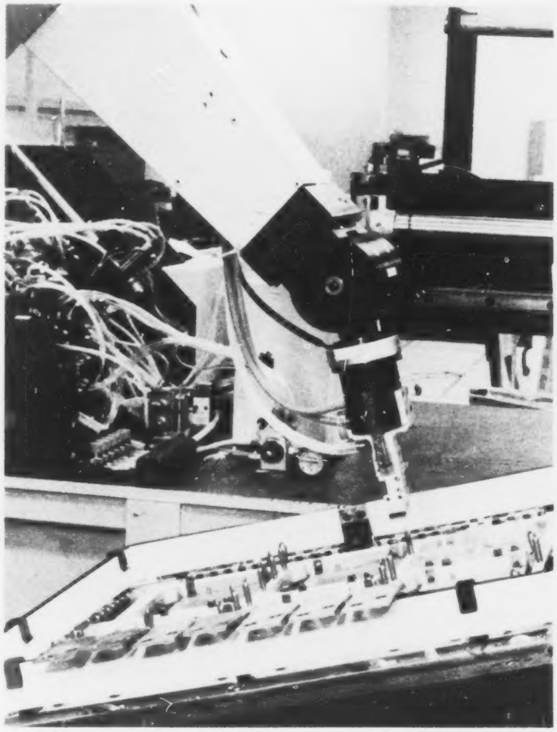

Photo credit: IBM Corp.

Advances in robotics and other technologies provide economic opportunities for a variety of regions

However, the technological opportunities in microelectronics remain too numerous for any one firm—or region—to exploit. Similar opportunities are also being opened by advances in other technologies, such as robotics and biotechnology. In addition, the applications of new products and manufacturing technologies also create new opportunities for declining industries and the regions in which they are concentrated.[13] Finally, the negative impacts of increasing concentration, combined with the maturation of the technologies themselves, have

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"Technological Innovation, Entrepreneurship, and Strategy," *Sloan Management Review*, spring, 1979, pp. 19-30; Karl H. Vesper, *Entrepreneurship and National Policy* (Chicago: Heller Institute for Small Business Policy, 1983); Stephen Feinman and William Fuentevilla, *Indicators of International Trends in Technological Innovation* (Jenkintown, PA: Gellmann Research Associates, 1976).

[10] George Gilder, "Should We Sacrifice Our Future To Preserve the Past?" *INC.*, vol. 2, No. 11, November 1980, pp. 93-98; Devendra Sahal, "Technology, Productivity, and Industry Structure," *Technological Forecasting and Social Change*, vol. 24, 1983, pp. 1-13.

[11] Devendra Sahal, "Invention, Innovation, and Economic Evolution," *Technological Forecasting and Social Change*, vol. 23, 1983, pp. 213-235.

[12] Dorfman, op. cit., p. 310; Donald L. Koch, William N. Cox, Delores W. Steinhauser, and Pamela V. Whigham, "High Technology: The Southeast Reaches Out for Growth Industry," *Economic Review*, Federal Reserve Bank of Atlanta, vol. 68, No. 9, September 1983, pp. 4-19.

[13] Lynn E. Brown, "Can High Tech Save the Great Lakes States?" *New England Economic Review*, November-December 1983, pp. 19-33.

led to dispersion of these boom industries out of their original seedbeds.

This creates opportunities for additional communities to attract production facilities, on which a local scientific and technical base can be built. In addition, some of the conditions that led to agglomeration in Silicon Valley and Route 128 can be replicated elsewhere, particularly those involving components of the *technological infrastructure* such as informal communication networks and institutional cooperation. The efforts of other States and localities to create these conditions are discussed in chapter 4. Their success in achieving long-term, sustainable HTD may depend on their ability to mobilize the resources created by branch plants as the ingredients for "home grown" HTD, and to encourage creation and expansion of indigenous firms by local entrepreneurs. The following section examines the process of technological entrepreneurship and the conditions that encourage and support it.

Entrepreneurship and High-Technology Development

Factors in the Promotion of Entrepreneurship

The individual inventor/entrepreneur has been respected, praised, and, during some periods in American history, elevated to the status of culture hero.[14] Despite fluctuations, there is a clear trend toward greater public appreciation of the entrepreneur following a partial eclipse during the 1960's and early 1970's.[15]

Favorable local and regional cultures can enlarge the pool of potential entrepreneurs. In the classic high-technology complexes of California and New England, for example, entrepreneurial activity is especially strong and highly respected: role models abound, starting one's own firm before age 35 is a common ambition, and it is not unusual for employees to leave a firm and start their own after seeing the success of a former colleague. When the entrepreneur becomes a local culture hero, the "cascading" of entrepreneurial activity may become almost explosive. An example is the 35 new firms spawned by former employees of Fairchild Camera between 1957 and 1970 (see fig. 3).

Much of the literature on entrepreneurship has been devoted to describing the psychological traits associated with successful individuals. Different researchers have emphasized different characteristics: innovation (the creation of new combinations of products and processes);[16] the search for novelty or opportunity in a climate of uncertainty;[17] or the need for achievement.[18] Entrepreneurs dislike repetitive work and tend to be nonconformists, but they are only moderate risk-takers.[19] Studies focusing specifically on high-technology entrepreneurs suggest that dissatisfaction with previous employment is often a factor in their decision to establish a new firm.[20] Extensive familiarity with the industry is the norm, and high-technology entrepreneurs tend to maintain widespread networks of informal contacts in the industry, often including former employers.[21]

This suggests that efforts to encourage HTD should include assistance from a network of specialists engaged in different aspects and stages of product creation, production, and marketing. This should not be seen as a denial of the importance of individual creativity and commitment, but instead as a recognition of the need for a supportive social environment for the entrepreneur.

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[14] Material in this section is based on the staff paper, "The Role of Entrepreneurship in High-Technology Innovation," December 1983, prepared for OTA by Professor Douglas Caulkins of Grinnell College while serving as a faculty intern.

[15] David C. McClelland, *The Achieving Society* (New York: Van Nostrand, 1961); Alex Inkeles, "The American Character," *The Center Magazine*, November/December 1983; Samuel Florman, *Blaming Technology: The Irrational Search for Scapegoats* (New York: St. Martin's Press, 1981).

[16] Schumpeter, op. cit.

[17] Ronen, op. cit., pp. 148-149; Yvon Gasse, "Elaborations on the Psychology of the Entrepreneur," in *Encyclopedia of Entrepreneurship*, Calvin A. Kent, Donald L. Sexton, and Karl Vesper (eds.) (Englewood Cliffs, NJ: Prentice-Hall, 1982), p. 59.

[18] McClelland, op.cit.

[19] M. F. R. Kets De Vries, "The Entrepreneurial Personality: A Person at the Crossroads," *Journal of Management Studies*, vol. 14, 1977, p. 38; Robert H. Brockhaus, Sr., "Elaborations on the Psychology of the Entrepreneur," op. cit., Kent, Sexton and Vesper (eds.), pp. 41-43.

[20] Brockhaus, op. cit., pp. 51-52; C. Comegys, "Cognitive Dissonance and Entrepreneurial Behavior," *Journal of Small Business Management*, January 1976.

[21] Brockhaus, op. cit., p. 51.

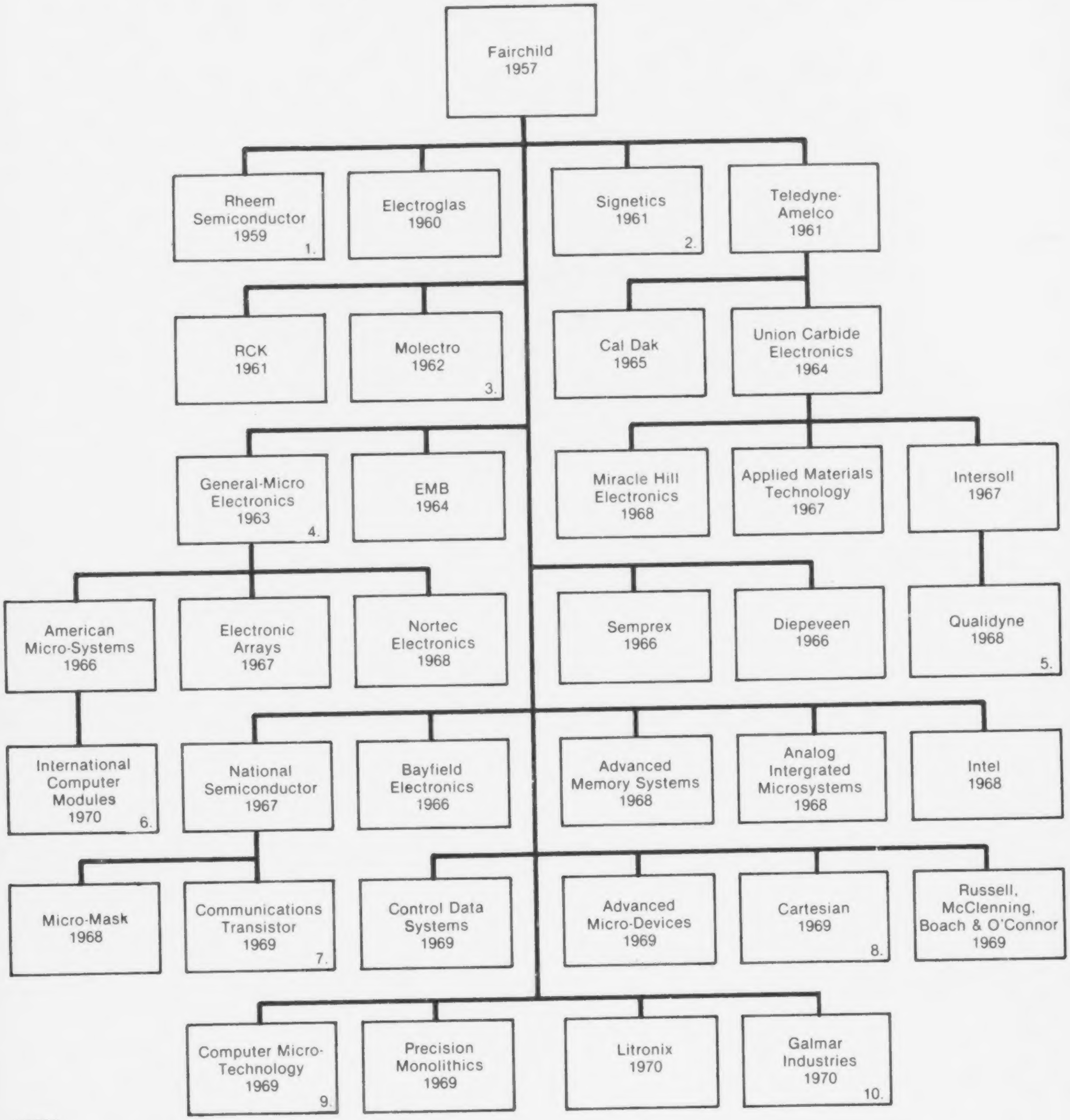

Figure 3.—Fairchild Begat Tree (1957-1970)

Fairchild 1957
Rheem Semiconductor 1959 1.
Electroglas 1960
Signetics 1961 2.
Teledyne-Amelco 1961
RCK 1961
Molectro 1962 3.
Cal Dak 1965
Union Carbide Electronics 1964
General-Micro Electronics 1963 4.
EMB 1964
Miracle Hill Electronics 1968
Applied Materials Technology 1967
Intersoll 1967
American Micro-Systems 1966
Electronic Arrays 1967
Nortec Electronics 1968
Semprex 1966
Diepeveen 1966
Qualidyne 1968 5.
International Computer Modules 1970 6.
National Semiconductor 1967
Bayfield Electronics 1966
Advanced Memory Systems 1968
Analog Intergrated Microsystems 1968
Intel 1968
Micro-Mask 1968
Communications Transistor 1969 7.
Control Data Systems 1969
Advanced Micro-Devices 1969
Cartesian 1969 8.
Russell, McClenning, Boach & O'Connor 1969
Computer Micro-Technology 1969 9.
Precision Monolithics 1969
Litronix 1970
Galmar Industries 1970 10.

NOTES:

1. Acquired by Raytheon in 1961.
2. Two founders were from Semiconductor Corp.
3. Assets of Molectro acquired in reorganization of National which moved from Connecticut to California.
4. Acquired by Ford-Philco in 1966.
5. Other founders were from Circuit Engineering & Design, Fairchild, GE, and Union Carbide.
6. Three founders from AMI, and three from Hewlett-Packard.
7. Two founders from Fairchild.
8. One founder from Philco-Ford Microelectronics.
9. Four founders from Fairchild , and one from ITT Semiconductor.
10. Two founders from Fairchild, and one from Semimetals, Inc., and one from Peripheral Systems Corp.

SOURCE: From Kirk P. Draheim, "Factors Influencing the Formation of Technical Companies" in Cooper and Komives, 1972; with permission.

Photo credit: Utah Innovation Center

Inventor-entrepreneur, right, from the Utah Innovation Center, and his High Frequency Jet Ventilator for infants and newborns

Entrepreneurial Networks

The essential role of the entrepreneurial network is to bring technological innovations successfully into the marketplace. The entrepreneurial process begins with the recognition of an opportunity for a new product, but it ends (if successful) with the routinized production and marketing of a commercial product. Technological entrepreneurship may begin with one individual's ideas, but it will necessarily involve many people and institutions before the process comes to an end. It is useful, therefore, to think not in terms of individual entrepreneurs but of *entrepreneurial networks*, the components of which are involved in different phases of the process.[22] Successful entrepreneurship within existing firms depends on assembling an appropriate team and creating communication networks across departmental boundaries.[23] For individual entrepreneurs, the region's technological infrastructure and numerous contacts in the industry can supply a similar support network.

Many entrepreneurial networks for new starts have been assembled fortuitously. The first step in the formation of new firms may occur when a potential entrepreneur is not encouraged by his present employer to pursue an innovation. In this case the frustrated employee may "spin off" a new company to develop the product himself. This may explain the greater instance of startups in regions that have a large number of existing firms in similar sectors.

The process of creating the firm—solving design problems, developing a business plan, obtaining financing, and assembling the needed management and technical team—is often a perilous task. Many high-technology firms do not survive beyond the first or entrepreneurial stage, often because the founding entrepreneur lacks the necessary managerial experience or skills. Existing high-technology complexes, because of their preexisting support networks and other agglomeration economies, serve to reduce risk and uncertainty. This has led to their reputations as successful "incubators" of new starts.

The experience gained during the past 30 years in Silicon Valley and Route 128 has demonstrated the importance of technological entrepreneurship to regional HTD. It has also created a sufficient knowledge base to support the deliberate cultivation of entrepreneurship and new starts.[24] Many of the functions that were previously performed informally, and even haphazardly, by components of the entrepreneurial network have now been institutionalized in the venture capital industry. In addition, a number of universities, often in collaboration with other public and private sector groups at the State and local level, have launched programs to train and assist potential entrepreneurs.

In an increasing number of cases, furthermore, existing firms encourage an employee to start a "spinout" firm by assisting with capital, laboratory space, and technical support. In these cases the parent firms themselves become (or provide) members of the entrepreneurial network. Tektronix and Control Data are among the firms which have assisted internal entrepreneurs with spinout firms.

Finally, a number of large corporations—in some cases early leaders in the high-technology field that are concerned about losing their innovativeness—have experimented with techniques for promoting

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[22] Lionel A. Cox, "Transfer of Science and Technology in Successful Innovation," *Forest Products Journal*, vol. 24, No. 9, September 1974, pp. 44-45.

[23] Rosabeth Moss Kanter, *The Change Masters: Innovation for Productivity in the American Corporation* (New York: Simon & Schuster, 1983), p. 28.

[24] "The New Entrepreneurs," *The Economist*, Dec. 24, 1983, pp. 61-73.

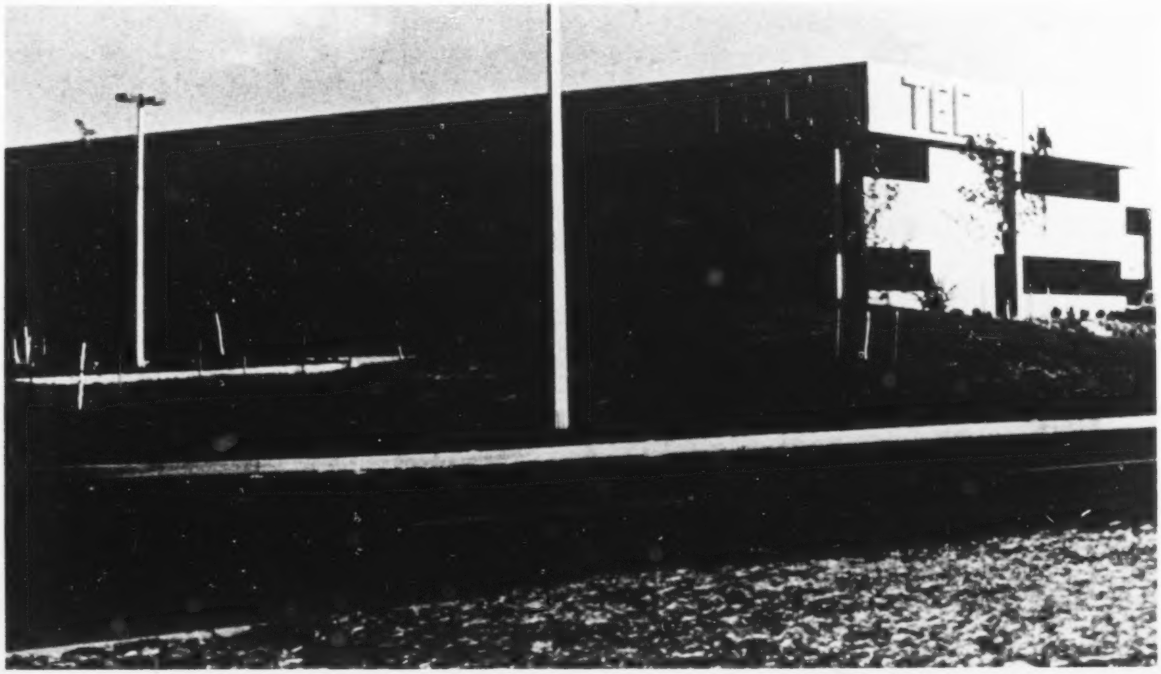

Photo credit: Tennessee Technology Foundation

Technology for Energy Corp. in Knoxville, a spinoff from the University of Tennessee and Oak Ridge National Laboratory

corporate entrepreneurship. Among the more successful organizational experiments have been the "venture management" or "incubator groups" set up within major corporations such as Xerox, Exxon, 3M, and IBM. These product-development units can have a core membership of persons with common skills, such as electrical engineering, with other specialists joining and leaving as needed during the development of an innovation. A second approach is to bring together individuals with different skills to carry the innovation through the entire cycle of development. The latter approach has generally been more productive of successful innovations, in part because it tends to minimize the potential discontinuity of the entrepreneurial network.[25]

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[25] Michael J. Brand and John Van Maanen, "Individuals, Groups, and Technological Innovation," *Chemtech*, September 1983, pp. 528-533.

Venture Capital and Regional High-Technology Development

Role and Structure of the Venture Capital Industry

Venture capital investment is primarily regarded as the *early stage financing* of relatively small, rapidly growing companies (see fig. 4).[26] [27] Since the recession of 1974, however, venture capitalists have taken on an expanded role in business development providing *expansion financing* for young companies that do not yet have access to public equity markets, and financing for *leveraged buyouts* in which managers purchase divisions of major corporations with the objective of revitalizing existing businesses.

Three key attributes characterize venture capital investment:

- It involves some potential *equity participation* for the venture capitalist, either through direct purchase of stock or through warrants, options, or convertible securities.
- It is a *long-term investment discipline* that often requires a period of 5 to 10 years for investments to provide a significant return.
- Venture capitalists are *active, ongoing participants* whose experience and specialized skills add value to their investment in a developing business; they are not passive investors offering only capital.

In a sense, therefore, the venture capital industry institutionalizes many of the functions, and benefits, of the technological infrastructure or entrepreneurial network. The assistance that venture capitalists provide to entrepreneurs and young growing businesses is usually in such areas as:

- long-range planning;
- defining financial needs and arrangements;
- market planning and marketing assistance;
- recruiting and evaluating management;
- finding external technical expertise and vendor/supplier relations; and
- contributing business experience through ongoing counsel and support.

These skills are learned through an apprenticeship process—younger associates spend years working for more experienced venture capitalists until they gain the requisite experience and credibility to form new firms. These spinoffs from existing firms have been a major source of growth in recent years, measured in terms of number of venture firms.

The formal venture capital industry consists of three major types of professional organizations: independent private venture capital firms; venture capital subsidiaries of financial and nonfinancial corporations; and Small Business Investment Companies (SBICs) (see table 10). Independent private firms include family groups and, to a greater extent, professional partnerships funded by both individual and institutional investors (see table 11). A number of financial corporations, most notably bank holding companies, have established venture capital subsidiaries to invest in businesses that do not meet the parent company's usual investment or loan criteria. In addition, many large industrial corporations (including General Electric, Lubrizol, Texaco, Textron, and Xerox) have venture capital investment groups.

Among the approximately 360 regular SBICs licensed by the Federal Government, some 200 are involved primarily in venture capital investment rather than loans to small businesses; this group of

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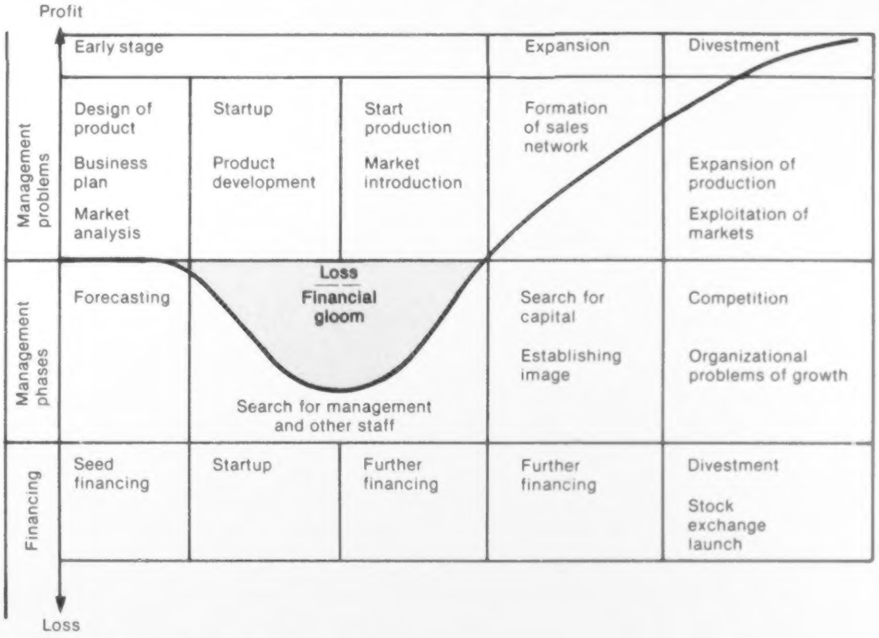
[26] The following sections are based on the contractor report, "Venture Capital Investment: Regional Variations," prepared for OTA by Venture Economics, Brian Haslett, principal investigator, December 1983. The statistics in the text and tables are derived from the Venture Economics data base, which contains information on the investments of venture capital firms and SBICs accounting for more than 80 percent of the industry's total investment activity and on more than 4,000 portfolio companies dating to the 1960's.

[27] Early stage financing can be defined in finer stages:

- *Seed*—a relatively small amount of capital provided to prove a business or technology concept. It may involve product development but rarely any marketing.
- *Startup*—financing provided for use in product development and initial marketing. Companies may have been in business a short time (1 year or less), but have not sold their product commercially.
- *First stage*—financing provided to companies that have expended initial capital (often in developing a prototype) and require funds to initiate commercial manufacturing and sales.

Figure 4.—Profile of a Company Startup by Venture Capital


Profit
Early stage
Expansion
Divestment
Management problems
Design of product
Business plan
Market analysis
Startup
Product development
Start production
Market introduction
Formation of sales network
Expansion of production
Exploitation of markets
Management phases
Forecasting
Loss
Financial gloom
Search for management and other staff
Search for capital
Establishing image
Competition
Organizational problems of growth
Financing
Seed financing
Startup
Further financing
Further financing
Divestment
Stock exchange launch
Loss

SOURCE: *Nature Magazine*, vol. 307, Feb. 3, 1984, p. 403.

Table 10.—Estimated Organized Venture Capital Pool, 1982

	Amount of capital under management (billions)
Private venture capital firms	$4.4
Corporate subsidiaries (financial and nonfinancial)	1.9
Small business investment companies[a]	1.3
Total	$7.6

[a]This includes only SBICs engaged primarily in equity investing.

SOURCE: Venture Economics, Inc.

SBICs includes many that are affiliated with bank holding companies. Other sources of risk capital available to entrepreneurs include the public new issues market, wealthy individuals, and local investors with a few dollars to back an acquaintance or relative. The term "informal investors" refers to the latter—financially sophisticated individuals who often have previous experience with new ventures.[28]

Recent History of the Venture Capital Industry

As is the case with any industry, the structure and behavior of the venture capital industry is greatly influenced by external factors.[29] Among the most significant of these are Federal tax policy with respect to capital gains; laws and regulations affecting pension funds and other major sources of investment capital; the market for new public stock offerings by small companies; and the track record of experienced professional venture capitalists themselves. Only a limited number of private venture capital firms existed in the 1950's, several of which were family funded firms. Passage of the Small Business Investment Act of 1958, which created the SBIC program, was a major influence on the development of the venture capital industry in the United States. By providing tax advantages, potential Government leverage, and a vehicle designed for small business

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[28] Informal investors are an appropriate source of external risk capital for many ventures, but few data are available on informal investment activity. The data, analysis, and observations presented in this chapter deal only with the formal venture capital industry.

[29] For a detailed examination of the venture capital industry, see U.S. General Accounting Office, "Government-Industry Cooperation Can Enhance the Venture Capital Process," GAO/AFMD-82-35, August 1982.

Table 11.—Commitments to Independent Private Venture Capital Firms

	1981		1982 (first six months)	
Source	Capital committed (millions)	Percent of total	Capital committed (millions)	Percent of total
Pension funds	$ 200	23	$484	34
Individuals and families	201	23	283	20
Insurance companies	132	15	199	14
Foreign	90	10	197	14
Corporations	142	17	170	12
Endowments and foundations	102	12	90	6
Total	$1,423	100	$867	100

SOURCE: Venture Economics, Inc.

financing, the Act encouraged the formation of hundreds of SBICs.

In the early 1960's, however, there were relatively few experienced venture capital managers, and many of these newly created SBICs failed. These failures discouraged many potential investors, and a declining public market for new issues in the early and mid-1970's forced venture capitalists to operate across a far broader spectrum of investment opportunities, particularly later-stage expansion financings, which provided adequate returns and a lower risk exposure than early stage investments. Underwritings fell from $1.4 billion in 1969 to only $16 million per year in 1974 and 1975, and high capital gains taxes combined with a depressed stock market to create an unfavorable environment for the industry. The total pool of organized venture capital was essentially static from 1969 through 1977.

Sharp reductions in capital gains taxes in 1978 made risk-taking by entrepreneurs far more rewarding and attracted a substantial influx of funds to venture capital firms. The total venture capital pool managed by professional firms grew threefold, from some $3 billion in 1977 to $9 billion at mid-year 1983. Moreover, recent changes in Federal regulations have made it easier for pension funds to invest in venture capital partnerships; as a result, approximately 30 percent of the new capital for professional firms—some $924 million between 1978 and 1982—has been provided by pension funds (see table 10). The successful track records of experienced venture capitalists (whose returns in many cases have only been realized and reported since the mid-1970's) have also attracted the attention of investors. Established venture capitalists are now bringing in record amounts of money.

The substantial increase in the venture capital pool has had an impact on the size of venture capital firms and on the scale and dispersion of venture capital investment activity. Several new venture capital "megafunds" run by small, well-respected management groups have attracted over $100 million. Most general-purpose funds, by contrast, range between $20 million and $30 million. These larger funds can make larger investments than have been traditional and still achieve diversity in their portfolios.

Factors Influencing Regional Distribution of Venture Capital

Focusing by Stage of Business Development.—The role of venture capital and the skills required of the venture capitalist vary considerably with each stage in the development of a portfolio company. A venture firm that concentrates on later-stage financing is generally dealing with more mature companies which require less attention, but the number of individual investments handled by each partner is still small. When a firm concentrates on early stage and startup investments, there are even fewer portfolio assignments per professional, since such investments usually involve more substantial involvement and time.

In recent years, however, a new group of venture capital "seed" funds have been formed to address the financing needs of very early stage companies. The financing of seed and startup ventures is an essentially local activity. Some venture capitalists cite, as an informal rule, that they do not wish to look at seed or startup situations more than 250 or 300 miles from their office. Thus, a focus on seed and startup investment situations will necessarily confine investments to the region where the venture firm is located. It follows, therefore, that entrepreneurs in an area with few or no venture capital firms focusing on seed or startup situations will have a more difficult time accessing venture capital than those in an area with numerous venture firms focusing on early stage financing. Later-stage financing requires less daily involvement by the venture capitalist, and thus investments can be sought from a broader geographic area.

However, the growth of these seed funds has been paralleled by the growth of informal "feeder" relationships between local seed funds, which often lack the capital to provide successive rounds of financing rapidly growing companies, and larger national funds that can provide portfolio firms with later-stage financing. For the larger firms, which may lack the manpower to identify and develop a large number of startups, this affiliate relationship is one way to provide themselves with a continuing flow of quality investments.

Focusing by Industry.—Venture capitalists often focus on particular industries, primarily because it is difficult to develop the requisite expertise in more than a handful of sophisticated technologies. This is particularly true for investment in electronics, biotechnology, and other high-technology industries.

A review of investments during the early 1980's indicates the following distribution of portfolio companies:

- computer-related fields—between 30 and 40 percent;
- communications—10 percent;
- other electronics-related areas—12 to 14 percent;
- medical-related areas—7 to 8 percent;
- genetic engineering—4 percent; and
- industrial automation—3 to 4 percent.

The remaining 20 to 34 percent of investments were in energy, industrial products, consumer-related areas, and other manufacturing and services.

The industry focus of a particular venture firm is a function of both the expertise of its professional staff and its geographical location—i.e., industries in the venture firm's "home market" which offer investment opportunities. Some venture capital firms, however, have hired partners with technical expertise to broaden their investment opportunities. Co-investment syndicates have also developed, allowing venture firms to expand their industry exposure by sharing technical expertise as well as risk. The expectations of the investors supplying the capital can also be a major determinant of investment strategy. Specifically, some corporate investors are looking for "windows" on new technology and are thus inclined to direct their venture capitalists towards particular industries and particular technologies.

Photo credit: McDonnell Douglas Automation Co.

Technological Infrastructure.—Another factor influencing regional variations in venture capital activity is the presence or absence of the professional, technical, and commercial services needed to support new high-technology firms. Those needed services include, but are not limited to, lawyers, accountants, commercial loan officers in banks and other traditional business lenders, R&D personnel, educators, large corporations, and responsive State and local government. How these professionals and institutions view the new business development and venture investment process clearly affects entrepreneurial activity and the concomitant investment of venture capital.

However, the outlook of lawyers, accountants, and loan officers tends to be conservative in many regions. Moreover, research staffs at large laboratories, major corporations, and leading educational institutions can also constrain entrepreneurial activity by focusing on proven technologies and resisting potential new applications. Business schools have tended to emphasize the administration of the large, established corporations rather than the processes by which new businesses develop.[30] Large corporations also frequently have the conservative biases associated with any large bureaucratic institution, and some seem to have lost the entrepreneurial spirit of their early days. Governments often use tax, land use, and other regulatory policies to preserve existing jobs and businesses rather than to create new entities.

The result is that a whole series of professionals and institutions with (often legitimate) conservative biases lack both the inclination to take risks—the essence of entrepreneurship and venture investing—and an understanding of this risk-taking process. Entrepreneurs seeking assistance from such professionals and institutions may be discouraged in their efforts. Investors expressing an interest in venture capital may be likewise discouraged.

A healthy venture investment climate in a region requires the existence of a cadre of professionals and managers in key institutions who understand the venture investment process and the requirements, particularly the risk-taking element, of the entrepreneurial and business-development process. Regions with a limited history of venture capital activity often need to develop this professional and institutional infrastructure if they wish to expand the volume of entrepreneurial activity and venture capital investment.

Traditional centers of venture capital activity and HTD have this kind of entrepreneurial network, and efforts are under way to replicate it elsewhere. For example, analysis of Route 128 and Silicon Valley suggests that the Massachusetts Institute of Technology and Stanford University made a significant contribution to the development of those two regions. Awareness of their potential contribution has led universities in other regions to become increasingly active in stimulating local entrepreneurial activity and business development. Similar initiatives have also been launched by State and local governments and by private sector groups throughout the United States. These activities are described in chapter 4.

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[30] Robert H. Hayes and William J. Abernathy, "Managing Our Way to Economic Decline," *Harvard Business Review*, vol. 58, No. 4, July/August 1980, pp. 67-77.

Recent Patterns of Venture Capital Investment Activity

Venture Capital Gaps and Efforts To Fill Them

Concerns have been raised that gaps in the availability and accessibility of venture capital may hinder the creation and expansion of new high-technology firms.[31] Two principal types of gaps are of interest to the present investigation: stage of development (especially at seed or startup stage), and regional. Recent evidence suggests that market forces are working to correct—not exacerbate—these potential gaps.

Seed Capital Gaps.—There is a significant obstacle to any rapid increase in professionally managed seed capital investment: the limited human resources of the venture capital community relative to the demands of new ventures. The new venture capital funds specializing in seed and startup capital are narrowing this gap, but most of them are based in the San Francisco and Boston areas. However, even large venture capital funds invest in one or two seed financings each year; these investments are the most time-intensive, but they often bring the greatest financial returns.

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[31] "Venture capital availability" refers to the amount of capital committed to venture capital firms and thus available for investment in businesses. "Venture capital accessibility," on the other hand, refers to how readily this available capital can be obtained by entrepreneurs seeking funding. "Venture capital investment activity" refers to the disbursement of that capital by venture capital firms as they make investments in companies.

In 1982, about 5 percent of venture capital financings were in seed stage companies, compared with about 19 percent in startups (product development and initial marketing), 44 percent in expansions (firms already shipping a product), and 11 percent in leveraged buyouts and other investments.[32] The amounts invested were more heavily skewed toward the later stages of development, but about half of the companies that received expansion financing had previously received seed, startup, and/or first-stage financing from professional venture capitalists. The percentages are likely to be somewhat biased toward expansion financings because venture capitalists continue to support companies already in their portfolios.

Regional Gaps.—As competition within the industry intensifies, venture capitalists are filling some of the geographical gaps that have existed since the mid-1970's. More and more new areas are being explored for investment opportunities, either by new funds or by branches and affiliates of venture capital firms located in major centers. Although New York, California, Massachusetts, and Illinois have the greatest concentration of venture capital firms, new partnerships have been formed since 1981 in 10 other States—Colorado, Connecticut, Georgia, Maryland, Ohio, Oregon, Rhode Island, Texas, Virginia, and Washington.

In addition, an unprecedented 110 new venture capital funds are currently seeking $3.5 billion of new venture capital. Of these, two-thirds are located in the four leading centers—the San Francisco Bay Area, New York City, Boston, and Chicago. Fairfield County in Connecticut and Minneapolis-St. Paul account for another 14 percent. But 12 States have potential new or enlarged funds: Colorado, Florida, Georgia, Iowa, Maryland, Michigan, Missouri, New Mexico, North Carolina, Pennsylvania, Texas, and Washington.

A recent analysis suggests, however, that increasing the amounts of venture capital being managed in a region will not, in itself, increase the amount of venture investment activity there. Instead, the impact of increased dollars on the number of companies financed varied markedly from State to State during the period 1977-82.[33] This supports the contention that local capital is only one of many important ingredients in the technological infrastructure necessary for new business development.

Venture Capital Sources

The geographical sources of formal venture capital are relatively concentrated and have not changed significantly in the last 3 years, despite a 60-percent increase in the size of the pool. Nevertheless, certain regions and States show an increased presence as a source of venture capital. Table 12, which presents the regional breakdown for 1980-82, shows that roughly 75 percent of formal venture capital comes from three regions—California/Southwest,

Table 12.—Sources of Venture Capital Investment, by Region, 1980-82

	1980		1981		1982	
Region	Amount invested (millions)	Share (percent)	Amount invested (millions)	Share (percent)	Amount invested (millions)	Share (percent)
California/Southwest	$217	25.9	$ 272	25.1	$ 371	27.6
New York/New Jersey	234	28.0	301	27.8	355	26.4
New England	171	20.4	247	22.8	282	21.0
Midwest	116	13.9	134	12.4	177	13.1
Mid-Altantic	63	7.5	72	6.6	62	4.6
Gulf Coast/Southwest	21	2.5	25	2.3	54	4.0
Pacific Northwest	4	0.5	10	0.9	19	1.4
Rockies	3	0.4	2	0.2	13	1.0
Plains	3	0.4	9	0.8	7	0.5
South	5	0.6	12	1.1	6	0.4
Total from known sources	$837	100.0	$1,084	100.0	$1,346	100.0

SOURCE: Venture Economics, Inc.

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[32] For data on the percentage breakdown of amount invested, see *Venture Capital Journal*, June 1982, p. 10.

[33] *Venture Capital Journal*, September 1982, p. 9; see also tables 14 and 15 below.

New York/New Jersey, and New England. The Gulf Coast/Southwest, Pacific Northwest, and Rockies showed significant increases in 1982, due primarily to investments originating in Texas, Washington, and Colorado respectively. Investments from the Midwest have increased steadily, while the Mid-Atlantic, South, and Plains States declined in both amount and share in 1982 after increases in 1981.

This pattern of concentration is confirmed in table 13, which compares the leading sources of venture capital by State for 1980-82. The top eight States represent over 90 percent of the pool, the top four States over 75 percent, and the top two States—California surpassed New York in 1982—account for half of the new venture capital sources in the United States. These States clearly dominate their regions, as well: Illinois and Minnesota, for example, provided 88 percent of the new venture capital from the Midwest.

Venture Capital Recipients

The regional pattern of venture capital distribution is even more concentrated than that of sources, as shown in table 14. For most of the past decade, venture capital investment activity has been concentrated in the California/Southwest region, specifically northern California. New England (specifically Massachusetts) has been a distant second, followed at an even greater distance by the Gulf Coast/Southwest (specifically Texas) and New York/New Jersey (specifically New York). These geographic investment patterns did not change significantly during the period 1980-82, although the total amount of new venture capital investments increased by 80 percent and the number of companies financed by 50 percent. The top two regions increased their dominance in 1982, accounting for 61 percent of the investments and 56 percent of the companies financed by the venture capital industry in 1982.

But as venture capital disbursements increased from $1.1 billion in 1980, to $1.4 billion in 1981, and $1.8 billion in 1982, even a constant percentage of the total investment means an increase in the amount of venture capital received. Investments increased significantly in the Midwest and Rockies, and the Pacific Northwest increased its share of both dollars and deals. The South and Plains have seen relatively flat levels of investment activity, however, and the Mid-Atlantic has experienced a steady decline in venture capital investment activity.

Table 15 shows a similar pattern at the State level: over 80 percent of all venture capital investment are concentrated in just 10 States. The top five venture capital recipients (California, Massachusetts, Texas, New York, and Colorado) did not change during the period, and their share of venture capital activity increased from 68 percent to almost 77 percent of total investments. California steadily increased its dominant position, accounting for almost 40 percent of the companies financed and over 45 percent of the amount invested in 1982.

The second tier of States are more volatile: New Jersey has risen slowly from tenth to seventh place, while Michigan suddenly appears in eighth place in 1982 on the basis of some rather large investments,

Table 13.—Leading Sources of Venture Capital, by State, 1980-82

	1980		1981		1982	
State of investor	Amount (millions)	Share (percent)	Amount (millions)	Share (percent)	Amount (millions)	Share (percent)
California	$216	25.8	$ 270	24.91	$ 370	27.5
New York	223	26.6	290	26.8	340	25.3
Massachusetts	144	17.2	171	15.8	167	12.4
Illinois	67	8.0	90	8.3	135	10.0
Connecticut	19	2.3	55	5.1	107	7.9
Texas	19	2.3	25	2.3	52	3.9
Pennsylvania	44	5.3	58	5.4	35	2.6
Minnesota	18	2.2	26	2.4	21	1.6
Eight-State total	750	89.6	985	90.9	1,227	91.2
Total from known sources	$837	100.0	$1,084	100.0	$1,346	100.0

SOURCE: Venture Economics, Inc.

Table 14.—Distribution of Venture Capital Investments and Companies Financed, by Region, 1980-82

Region	Year	Amount invested (millions)	Share (percent)	Companies financed	Share (percent)	Average amount invested per company (millions)
California/Southwest	1980	$ 350	34.1	208	34.2	$1.7
	1981	$ 599	42.5	247	34.4	$2.4
	1982	$ 833	45.7	353	39.3	$2.4
New England	1980	142	13.8	104	17.1	1.4
	1981	239	17.0	138	19.2	1.7
	1982	278	15.3	148	16.5	1.9
New York/New Jersey	1980	91	8.9	55	9.0	1.7
	1981	80	5.7	65	9.1	1.2
	1982	173	9.5	80	8.9	2.2
Gulf Coast/Southwest	1980	132	12.9	62	10.2	2.1
	1981	162	11.5	57	7.9	2.8
	1982	158	8.7	76	8.5	2.1
Midwest	1980	82	8.0	60	9.9	1.4
	1981	109	7.7	73	10.2	1.5
	1982	124	6.8	72	8.0	1.7
Rockies	1980	68	6.6	33	5.4	2.1
	1981	55	3.9	36	5.0	1.5
	1982	82	4.5	47	5.2	1.7
South	1980	54	5.3	39	4.3	1.4
	1981	59	4.2	35	4.9	1.7
	1982	62	3.4	38	4.2	1.6
Mid-Atlantic	1980	76	7.4	26	6.4	2.9
	1981	65	4.6	35	4.9	1.9
	1982	52	2.9	44	4.9	1.2
Pacific Northwest	1980	20	2.0	18	3.0	1.1
	1981	33	2.3	25	3.5	1.3
	1982	50	2.7	32	3.6	1.6
Plains	1980	10	1.0	3	0.5	3.3
	1981	8	0.6	7	1.0	1.1
	1982	10	0.5	8	0.9	1.2
United States	1980	$1,025	100.0	608	100.0	$1.7
	1981	$1,409	100.0	718	100.0	$2.0
	1982	$1,822	100.0	898	100.0	$2.0

SOURCE: Venture Economics, Inc.

and Minnesota appears in ninth on the basis of a larger number of smaller investments. Illinois, although a growing source of venture capital (see table 13), experienced a decline in the share invested in the State; Connecticut, on the other hand, is becoming more prominent as both a source and a recipient of venture capital.

Interregional Flows

Many of the differences between regions or States as sources versus recipients of investment can be explained by the mobility of venture capital. Table 16 presents in matrix form the flow of venture capital between regions in 1982. The California/Southwest region owes its dominance to two factors: 75 percent of the venture capital originating in the region was also invested there, and it also attracted almost one-half of the investments made by venture capitalists in other regions. On average, in fact, only 25 percent of the venture capital raised in other regions was invested in the same region; New England invested only 33 percent of its venture capital in local companies. Only in the South and Pacific Northwest was the majority of venture capital invested at home: in the South, a number of small SBICs have concentrated their limited resources on investments close to home; in the Pacific Northwest, one major firm has made investment in emerging Northwest companies a major focus of its strategy.

Table 15.—Regional Flow of 1982 Venture Capital Investment (millions of dollars)

	Region of venture capital recipient										
Region of investor	New England	New York/ New Jersey	Mid-Atlantic	South	Midwest	Gulf Coast/ Southwest	Plains	Rockies	California/ Southwest	Pacific Northwest	Total by region of investor [a]
New England	$ 93	$ 19	$ 6	$ 9	$ 7	$ 20	$ 1	$ 7	$118	$ 3	$ 282
New York/New Jersey	61	66	15	11	15	31	3	14	136	3	355
Mid-Atlantic	5	2	4	2	1	3	—	—	42	1	62
South	—	—	—	3	—	2	—	1	—	—	6
Midwest	16	5	12	5	38	12	2	17	64	6	177
Gulf Coast/Southwest	9	—	—	4	1	24	—	5	7	1	54
Plains	—	—	—	—	2	2	1	1	2	—	7
Rockies	—	1	—	—	—	1	1	3	7	—	13
California/Southwest	33	7	1	2	5	22	—	13	280	8	371
Pacific Northwest	—	—	—	—	—	—	—	1	8	11	19
Foreign investors	10	11	2	4	10	3	—	2	36	1	78
Region unknown[b]	51	61	13	22	44	38	2	19	134	14	398
Total by region of recipient	$278	$173	$52	$62	$124	$158	$10	$82	$833	$50	$1,822

— Investment of less than $1 million.

[a] Due to rounding, in some cases table entries do not equal the row or column totals.

[b] This category includes investors for which no location is identified as well as financing from unidentified investors. For example, in a $5 million financing, three of the venture capital investors may be unknown accounting for $4 million but the source of the additional $1 million may be unidentified. In some cases the unidentified investor may be a venture capital fund which prefers to keep a low profile or a firm which only makes occasional investments.

SOURCE: Venture Economics, Inc.

Table 16.—Leading Venture Capital Recipient States, 1980-82

	1980			1981			1982					
Rank	State	Share of investment (percent)	Share of companies financed (percent)	State	Share of investment (percent)	Share of companies financed (percent)	State	Amount invested (millions)	Share (percent)	Companies financed	Share (percent)	Average invested per company (millions)
1	CA	33.7	33.1	CA	41.7	32.7	CA	$ 829	45.5	349	38.9	$2.0
2	MA	12.0	13.8	MA	12.8	14.5	MA	224	12.3	114	12.7	2.0
3	TX	10.5	7.6	TX	9.9	5.6	TX	143	7.8	68	7.6	2.1
4	NY	6.5	4.9	NY	3.2	6.8	NY	134	7.4	59	6.6	2.3
5	CO	5.3	3.9	CO	3.1	3.9	CO	67	3.7	35	3.9	1.9
6	PA	4.1	2.3	CT	2.7	2.6	CT	39	2.1	23	2.6	1.7
7	IL	2.8	3.1	OH	2.6	2.2	NJ	38	2.1	21	2.3	1.8
8	GA	2.5	1.6	NJ	2.5	2.2	MI	34	1.9	13	1.4	2.6
9	MD	2.4	0.7	IL	2.3	2.8	MN	32	1.8	26	2.9	1.2
10	NJ	2.3	3.9	PA	2.1	2.4	PA	30	1.6	17	1.9	1.8
10-State total		82.1	75.0		82.8	75.8		$1,570	86.2	725	80.7	$2.2
U.S. total		100.0	100.0		100.0	100.0		$1,822	100.0	898	100.0	$2.0

SOURCE: Venture Economics, Inc.

Future Trends in Venture Capital Distribution

Only a relatively small number of pension funds have invested in venture capital firms to date, but as this investment alternative becomes more widely accepted more pension funds are expected to participate. Major corporations are also recognizing venture capital as a "window" on emerging technologies, and this recognition may also stimulate capital inflow. Venture capital investment is also becoming more international in scope: foreign investors have provided an increasing portion of the funds raised in the last 3 years; in the first 6 months of 1983, foreign sources supplied 21 percent of the $1.15 billion raised, second only to pension funds (see table 11). In addition, European investors are increasingly investing directly in U.S. portfolio companies along with U.S. venture capitalists, thereby leveraging the domestic investment pool.

Underlying technological changes favorable to entrepreneurial activity also seem likely to accelerate, thereby creating more investment opportunities. Demographic factors will also affect entrepreneurial activity, as a generation of American managers and engineers reach the "entrepreneurial age bracket," between 30 and 45, when individuals have accumulated the experience and capital needed to launch a new enterprise. A continuing constraint on the expansion of venture capital activity will be the industry's human resource base, but as more individuals gain experience through the apprenticeship process it should be possible to sustain the growth of the industry.

In addition, many State and local governments have begun to focus their attention on entrepreneurship and the venture capital process as part of their broader economic development strategies. These initiatives, which are discussed in the following chapter, often include efforts to increase the amount of risk capital available to local entrepreneurs. Venture capitalists have played an active role in designing these programs, and very few of them involve government-run investment funds. This reflects an emerging consensus that State-run funds would have difficulty in securing private coinvestors, retaining experienced venture capital managers, or resisting short-term pressures on investment decisions. Instead, most efforts involve public/private cooperation to enhance the venture capital process itself. Public sector roles in this effort have included:

- encouraging private investment by reducing State taxes on capital committed to new companies;
- enabling State employee pension funds to invest in venture capital partnerships;
- helping venture capital firms to secure capital from sources within the State;
- facilitating the seed capital process by providing local entrepreneurs with training, technical assistance, and help in preparing presentations to venture capitalists; and
- developing communications networks with the national venture capital community, in order to bring local opportunities to their attention.

CHAPTER 4

State and Local Initiatives for High-Technology Development

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CHAPTER 4

State and Local Initiatives for High-Technology Development

Introduction

In the past 10 to 20 years, several regions of the United States have developed strong local economies based on fast-growing "high-technology" industries. Encouraged by these successes, State and local governments, universities, and private sector groups are launching initiatives to promote similar high-technology development (HTD) in other regions.[1] They are optimistic because high-technology industries are spreading beyond their original strongholds, and because recent policy changes have shifted more of the responsibility for economic development to the State and local levels. While high-technology industries represent no more than 15 percent of total U.S. employment, they play a major role in many local economies and could be a force in the revival of distressed regions and cities, especially in the Midwest.

The intense competition for HTD has generated literally hundreds of State and local initiatives, but it is too soon to tell whether they have anything more than a marginal impact on HTD. Some critics view such competition as a zero-sum game—i.e., resources spent to entice a firm to locate in one city or State rather than in another are wasteful from a national viewpoint since no new jobs result. But States and cities are also beginning to take a number of actions to encourage technological innovation and economic activity that would not happen without government intervention.

These institutional innovations seek to strengthen the linkages among the financial, academic, and business communities; promote entrepreneurship; and improve the overall scientific and technological base of State and local economies. In short, the initiatives attempt to develop the cooperative support networks that constitute the technological infrastructure for HTD, either by mobilizing the necessary local resources or removing barriers to innovation and entrepreneurship.

The initiatives are as varied as the locales in which they were launched, but they seem to share three common goals: job creation, business development, and economic diversification. This chapter examines the roles played by the principal actors in State and local HTD and the interdependence of their efforts. However, the main emphasis of the chapter is on describing the goals and impacts of specific types of initiatives. Although most of these initiatives are very recent, some successes can already be identified. The final section of the chapter examines the factors that may increase the chances of success.

The Actors

State and local governments, universities, and private sector groups have all become more active in encouraging HTD, and their roles are examined below. This organization is somewhat misleading, however—only rarely are the initiatives completely independent. For example, State government programs usually involve the participation of university, local government, and/or private sector groups, just as university and local initiatives often seek to create closer and more productive relationships with private industry. Federal Government programs have also played at least an indirect role: many of the initiatives were encouraged by Federal pilot studies, and others have made innovative use of Federal funds, planning grants, and other development tools.

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[1] These initiatives have been described in detail in two OTA background papers: *Census of State Government Initiatives for High-Technology Industrial Development*, OTA-BP-STI-21, May 1983; and *Encouraging High-Technology Development*, OTA-BP-STI-25, February 1984.

State Government

High-growth, technology-based firms and the industries they compose have become the targets of increasingly numerous State economic development strategies. In some cases, the strategies involve organizational innovations designed to identify, integrate, and mobilize existing State resources for technological innovation. The strategies also often include the redirection of existing activities or the creation of new programs specifically designed to promote HTD. An OTA census conducted in January 1983 identified 153 State government programs with at least some features directed toward HTD; of these, 38 were specifically dedicated to the creation, expansion, attraction, or retention of high-technology firms.[2]

In order to gather more detailed information on State government initiatives, OTA conducted a survey and comparative analysis of high-technology initiatives in 16 States—8 that had implemented dedicated programs before 1981, and 8 that initiated dedicated programs in 1981-82.[3] The sample States selected for the survey were:

Pre-1981 States	*1981-82 States*
California	Indiana
Connecticut	Illinois
Georgia	Michigan
Massachusetts	Minnesota
New York	Missouri
North Carolina	New Mexico
Tennessee	Ohio
Pennsylvania	Rhode Island

OTA found that these States approach HTD in many ways. States with dedicated initiatives, for example, often had a sophisticated research base and considerable high-technology industry before those programs were established; their objective in part is to strengthen and retain what is already there. States whose economic base consists primarily of older, basic industries tend to emphasize economic diversification and the application of new production technologies in traditional manufacturing sectors. Still other States, notably the less highly industrialized ones, aggressively pursue the production facilities of expanding high-technology firms in order to bolster their industrial base and build a foundation for future development.

These approaches suggest that attention to HTD is not distinct from economic development activities in general. In most cases, State officials consider their high-technology initiatives to be a natural and even inevitable extension of their different economic development strategies. In many cases, the office responsible for HTD emerged through the evolution of a more traditional economic development agency.

OTA's investigation found that many initiatives involved both short- and long-term goals, and that most were well integrated with other State efforts. Often a high-technology task force or commission appointed by the Governor is the primary mechanism for identifying needs and formulating policy recommendations; the Governor's office was the initiator of more than half the programs investigated. Legislatures also play a role, since programs may require enabling legislation and legislative appropriations. However, that role varies widely, from little or no involvement to being the primary impetus in HTD efforts. Similarly, the State economic development office takes a lead policy role in some States, but plays a less direct role in others.

Most of the State initiatives studied involved the participation and support of university officials and business leaders. However, local governments were directly involved in fewer than half of these State programs; they generally participated indirectly, through their legislative representatives. The private sector most often provided advice and consultation, although that sector has been the primary initiator of certain State programs. University officials also advised, but they too have been the driving force behind certain programs.

About one-third of the programs in the survey States were classified as "labor and technical assistance" (primarily training programs). States with older initiatives had a slightly higher percentage of "high-technology education" programs, which may reflect their greater university resources. States with more recent initiatives had a slightly higher percentage of "general industrial development" programs with special provisions for high-technology firms, as well as programs involving capital assistance. However, while many financial assistance programs help firms to locate seed or venture capital, very few provide risk capital themselves.

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[2] *Census of State Government Initiatives for High-Technology Industrial Development* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-BP-STI-21, May 1983).

[3] *State Initiatives Survey*, prepared for OTA by the Research Triangle Institute, Alvin M. Cruze, principal investigator, May 1983.

Most of the 153 initiatives were launched between 1980 and 1983, and the vast majority (85 percent) have undergone no formal evaluation. Nevertheless, most survey respondents—State officials and high-technology executives alike--would favor additional initiatives by both State and Federal Governments.

The Task Force on Technological Innovation of the National Governors' Association (NGA) has reported that, while most States are actively pursuing short-term efforts to compete for technology-based research and manufacturing firms, they are also developing medium- and long-term strategies to encourage modernization in traditional industries and to create a favorable environment for entrepreneurship and technological innovation. As a result of these activities, according to the NGA report, both the impetus for technological innovation and "the real and effective initiative for economic development and for the provision of jobs are shifting from the Federal Government to the States." While the report asserts that "the preliminary results to date have been impressive," it acknowledges that most of these State initiatives are too new to evaluate.[4]

Local Government

Substate and local HTD efforts are driven by the prospect of increased jobs and a stronger tax base. The localities are often influenced by the tremendous contributions that high-technology companies have made to the local economies of Silicon Valley and the Boston area; indeed, some communities have sought to promote themselves as "Silicon Mountain," "Silicon Coast," or "Silicon Plain." OTA has identified five types of communities, based on the degrees of difference between the successful high-technology models and the localities that seek to emulate them:

- *high-technology centers,* which already have a strong base of high-technology firms, research universities, and venture capital;
- *diluted high-technology centers,* whose large high-technology base is spread through a larger and more mature local economy;
- *spillover communities,* located near high-technology centers, whose proximity allows them to exploit the centers' resources, amenities, and high-technology base;
- *technology installation centers,* where the presence of a major research facility attracts specialized suppliers and creates a local base of researchers and skilled workers that can be exploited for economic development; and
- *bootstrap communities,* which lack most of the characteristics of high-technology centers but offer low operating costs and high quality of life that make them attractive for branch plants of expanding high-technology companies.

In order to determine what types of local HTD programs have been attempted, how well they have worked, and their transferability to other communities, OTA analyzed 54 separate high-technology initiatives in 22 communities:[5]

Huntsville, AL
Phoenix, AZ
San Diego, CA
Colorado Springs, CO
Brevard County, FL
Orlando, FL
Chicago, IL
Lowell, MA
Montgomery County, MD
Minneapolis, MN
Albuquerque, NM
Binghamton, NY
Cincinnati, OH
Portland, OR
Philadelphia, PA
Oak Ridge, TN
Austin, TX
San Antonio, TX
Salt Lake City, UT
Burlington, VT
Seattle, WA
Milwaukee, WI

The most common types of substate and local initiatives identified in this investigation include the following:

- land use, planning, and zoning;
- university improvements;
- vocational-technical training;
- incubator buildings;
- marketing programs;

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[4] Task Force on Technological Innovation, *Technology and Growth: State Initiatives in Technological Innovation* (Washington, DC: National Governors' Association, October 1983). See also *State Initiatives in Technological Innovation: Preliminary Report of Survey Findings* (Washington, DC: National Governors' Association, February 1983).

[5] *Local High-Technology Initiatives Study,* prepared for OTA by The Fantus Co., Charles Ford Harding, principal investigator, April 1983.

- high-technology task forces; and
- venture capital.

While some initiatives sought to stimulate the creation of new local companies built around innovative products, the localities directed their greatest efforts toward attracting branch operations of large high-technology firms, which pay more immediate dividends in terms of job creation.

The programs of the 22 communities studies have not been subjected to rigorous comparative analysis or evaluation, and thus their value in helping to create high-technology centers cannot be determined.

Universities

Colleges and universities play two major roles in technological innovation and its diffusion through the economy. First, they train and educate scientists and other technical personnel and expand the base of scientific and technical information. Second, they transfer this talent and information to the private sector, thereby fostering the commercialization and diffusion of innovation. This cooperation between the educational and industrial sectors is not a new phenomenon—Stanford Industrial Park, which dates from the 1940's, and Research Triangle Park, developed in the 1950's, are primary examples of such cooperation.

The need for this interaction is even greater today. Universities, industry, and State governments have developed programs to address not only the preparation of students but also the needs of new and expanding high-technology businesses, particularly the need for increased research and development (R&D) and technology transfer and the need to provide technical/vocational skills to the local work force.[6] As the growth of Federal R&D funding has slowed in the face of inflation and budgetary pressures, the education sector has become more active in soliciting research funds from industry. In turn, industry supports university R&D because it requires the long-term, basic research on which universities concentrate.

OAK RIDGE
ASSOCIATED
UNIVERSITIES

Photo credit: Tennessee Technology Foundation

Oak Ridge Associated Universities, a nonprofit association of more than 50 colleges and universities acting as prime contractor for high-technology research, training, education, and information activities

A study by the U.S. General Accounting Office (GAO) concludes that these developing linkages between university and industry not only can enhance technological innovation but also can stimulate regional economic development.[7] Research and science parks affiliated with universities attract new high-technology firms to their areas, and they may also provide seedbeds for spinoff companies. Technical centers and industrial extension services benefit existing local businesses by increasing the rate of innovation diffusion and increasing access to facilities, equipment, and expertise. Cooperative research activities provide industry with early access to the results of university research and improved training for scientific and engineering personnel, according to the GAO study.

Institutional differences between the university sector and industry can make such cooperation and collaboration difficult. However, several of the newest contract agreements between industry and universities reflect possible resolutions, including the right of individual university researchers to publish their findings. Another issue is the ownership of intellectual property, particularly in light of the increased patentability of university-conducted applied research.

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[6] The material relating to universities is drawn from the following documents:

- U.S. General Accounting Office, *The Federal Role in Fostering University/Industry Cooperation*, GAO/PAD 83-22, May 1983;
- U.S. National Science Foundation, *University/Industry Research Relationships: Myths, Realities and Potentials*, NSB 82-1, October 1982;
- "Universities Emerge as an Important Catalyst in the New Business Development Process," *Venture Capital Journal*, vol. 23, No. 8, August 1983, pp. 7-12; and
- National Governors' Association, Task Force on Technological Innovation, *Technology and Growth: State Initiatives in Technological Innovation*, October 1983.

[7] GAO, op. cit., pp. 15, 24, 40, 47-48.

In addition, several States are working with their public universities to set up programs to stimulate innovation and business development. A number of community and junior colleges, in collaboration with their State, local government, or local industry, are providing training in technical skills needed by high-technology industry. In some cases, these programs take the form of a general training course; in others, these institutions work directly with a local firm to train the labor needed for expansion. The private sector also is cooperating with State and local governments to improve the quality of math and science education, and to provide training, retraining, and employment development.

The Private Sector

Private sector participation is an important feature in the design, operation, and success of HTD initiatives at the State and local levels.[8] These HTD efforts, after all, are aimed at influencing the decisions of individual entrepreneurs and firms about where to start, expand, or relocate their business activities. Increasingly, however, corporations and individual executives are participating as a stimulus or collaborator in HTD efforts of State governments, local communities, and universities. Business is directly affected not only by business conditions but also by conditions in the external environment. During the 1970's, State and local governments and the private sector began to assume a larger role in community development, and the early 1980's have seen further reductions in Federal funding for economic development and a further transfer of responsibility to local jurisdictions. The effort to secure additional public and private resources has led to the creation of local partnerships involving Government, community groups, and the private sector. This trend, reinforced in many cases by similar changes in State policies, is expected to continue.

Studies by SRI International indicate that this changing environment represents both a challenge and an opportunity for the private sector: local governments sometimes lack the manpower and experience to deal with the complex problems of HTD, while corporate action or public/private partnership has proven especially successful in such areas as economic development, job creation, and education and training. SRI also found that there are several different approaches that any company can undertake, regardless of its size.[9]

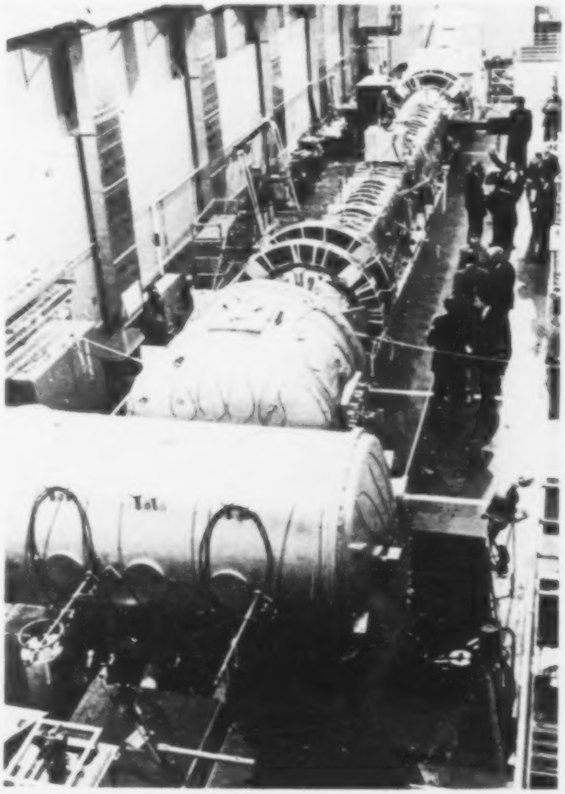

Photo credit: Massachusetts Institute of Technology

MIT's fusion research laboratory is named after Nabisco Brands, Inc., which donated the laboratory building

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[8] The following material is based on the contractor report, *Private Sector Initiatives: High Technology and the Local Economy*, prepared for OTA by Renee A. Berger with research assistance by Robert Guskind, April 1983.

[9] Tom Chmura, et al., *Redefining Partnership—Developing Public/Private Approaches to Community Problem Solving: A Guide for Local Officials* (Menlo Park, CA: SRI International, January 1982), p. 6. See also SRI International, "Developing Public/Private Approaches to Community Problem Solving," *Management Information Service Report* (International City Management Association), vol. 14, No. 7, July 1982, whole issue. Both reports are based on research conducted by the Public Policy Center of SRI International, with funding from the Office of Community Planning and Development of the U.S. Department of Housing and Urban Development.

Business involvement in regional HTD often results from company policies that reflect the personal beliefs and commitment of their executives. In other cases, business involvement addresses community problems that affect the general business climate or a particular firm's operating costs and profits: adequate public services and facilities in order to operate and grow; a well-trained labor force; and a reasonable local tax burden. An important byproduct of public/private ventures is the improved communication and understanding that results between participants from local government and the business community.

Private sector firms and executives have a wide range of resources that can be applied to problem-solving and economic development in their communities. Different types of firms possess different kinds of resources, and these resources often determine the roles firms play, the problems they address, and the specific initiatives they launch. In general, however, these strategies can be classified as follows:

- business investment and operations, notably site location decisions, but also including targeted bank deposits and real estate development, preferential hiring or procurement practices, and expanded employee services;
- education development, including philanthropic contributions, loaned personnel, donated equipment, technology transfer mechanisms, and cooperative research arrangements;
- business development and risk capital, including entrepreneurship training and assistance, small business incubators, and geographic investment pools for venture and seed capital; and
- business/civic advocacy, usually through trade or business executive associations, to express support for public leaders or policies, encourage participation by other firms, and promote community involvement by individual employees.

These four strategies are generic to all businesses, but the resulting initiatives show distinctive patterns associated with particular industries. Financial institutions, for example, find investment and business development a logical extension of their normal activities; their decisions are motivated by profit, but they also take into consideration the special needs of the community, such as housing or neighborhood revitalization. Nonfinancial corporations, on the other hand, are more likely to use philanthropic contributions as the mechanism for community involvement. in addition, patterns of involvement often reflect the particular self-interest of the firm: pharmaceutical companies make donations to medical schools, accounting firms give to business schools, and high-technology firms focus their donations on engineering or computer science programs.

High-technology firms have made use of all of these strategies. As nonfinancial institutions, they seldom use special investment strategies, but high-technology businesses have made substantial contributions to educational institutions, often commingled with investments in cooperative R&D programs. Company size affects the firm's ability to draw upon internal resources: large, well-established firms such as IBM, Honeywell, Sperry, or Xerox are able to draw upon vast amounts of capital, personnel, business experience, and a longstanding network of contacts. Also, as with other corporations, high-technology firms tend to focus their involvement near the headquarters, although there are numerous examples of company involvement at branch sites.

Federal Government Involvement

Representatives of the Federal Government have participated directly in the initiatives of several cities. For example, the High Technology Task Force in Chicago was chaired by the director of the Argonne National Laboratories. Major Federal R&D installations frequently have provided the base around which high-technology programs are built. In fact, the reduction of Federal support for such installations has provided the impetus for some local economic development programs directed at high-technology companies. Also, military bases have proved to be good sources of skilled labor for high-technology companies located in an area. In such cases, the Federal Government has in effect subsidized technical training for workers who subsequently feed into the local private economy.

In addition, many of these State and local HTD initiatives made extensive use of funding and development tools provided by the Federal Government. In its survey of 54 local HTD initiatives, for example, OTA found that the 22 communities surveyed had made use of several Federal programs:

Urban Development Action Grants	9
Industrial Development Bonds	5
Economic Development Administration grants	4
Community Development Block Grants	3
Comprehensive Education and Training Act programs	2
Free Trade Zone	2
Appalachian Regional Commission programs	2
Small Business Administration loan programs	1

These Federal programs were not designed specifically to help with regional HTD. Block grants, training programs, planning grants, and loan funds are highly flexible instruments and have been used for a variety of projects, depending on the needs or desires of different communities. When used imaginatively and in conjunction with other efforts by entrepreneurial local leaders, these programs have proven to be an effective adjunct to regional HTD efforts. (A more detailed discussion of the role of Federal policies and programs is presented in ch. 5.)

The Initiatives

The preceding section suggests the diversity, as well as the interdependence, of the roles played by State and local groups in promoting regional HTD. In most cases, however, their efforts are aimed either at mobilizing the necessary local resources or at removing barriers to HTD. The emphasis of the resulting initiatives falls into six general categories:

- research, development, and technology transfer;
- human capital;
- entrepreneurship training and assistance;
- financial assistance;
- physical capital; and
- information gathering and dissemination.

Research, Development, and Technology Transfer

Perhaps the most fundamental initiatives are those that aim to quicken the flow of innovation itself. Since most basic research is still performed by universities, many of these initiatives focus on improving linkages between universities and industry. Some, such as joint research ventures and research consortia, involve formal, long-term collaboration between a university and one or more companies. Others, such as research centers and technical extension services, provide technical assistance or perform short-term research for local firms in exchange for fees or other support. In other cases, alumni groups have become active in patenting and commercializing the results of university research.

In all of these cases, the object of the initiative is to make university resources more widely available, to raise the level of formal and informal communication between academic and industrial researchers, and to increase the speed with which research results become available to industry. Recent studies suggest that, given strong leadership and a stable source of funding, such initiatives can contribute to regional economic development by reorienting university research toward the needs of industry, by attracting outside firms to the region, by improving the productivity of existing firms, or by encouraging the creation of new firms.[10]

The OTA census found a number of State high-technology initiatives directed toward research, development, and technology transfer. For example, the Pennsylvania Technical Assistance Program offers technical information and assistance to all State businesses, particularly in the area of technology transfer. Other initiatives offer services to a specific set of industries or businesses involved in technological innovation. The Biomedical Research Park, a joint effort between Illinois and Chicago, is set up to assist biomedical firms with innovation and development.

University initiatives in industrial R&D are driven in part by the need to diversify funding sources, retain faculty, and attract students. However, changing technological and economic conditions have also led to a greater emphasis on commercializing research results, particularly when the university has royalty rights. These university initiatives include:

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[10] NSF, op. cit., p. 11.

- *research and science parks,* clusters of research-intensive firms and facilities on a site near a university;
- *research and technical centers* that disseminate information, provide technical assistance, and perform short- or long-term research for local businesses in exchange for fees and other support; and
- *university/industry collaboration,* including cooperative research ventures and research consortia.

University-based research centers perform applied research in exchange for fees and other support, allowing firms to pool their resources and thereby avoid duplicated expenses for facilities and equipment. The university benefits from the fees and increased research activities and from improved student training. The concentration of technical know-how can make these research centers fertile ground for creation of new high-technology businesses. Because these centers also have been cited as a major factor in the development of high-technology complexes, a number of States have begun to encourage their development.

For example these research centers include the North Carolina Center for Microelectronics, the Center for Applied Microelectronics at the University of Wisconsin, and the California Microelectronics Innovation and Computer Opportunities (MICRO) research center. The University of Minnesota has joined the ranks of microelectronics research centers by raising $6 million from businesses in the State. The Surface Science Center at the University of Pittsburgh will provide basic and applied research results applicable to industrial technologies, and the University of Wyoming has set up an Industrial Fund to provide applied research results to area businesses.

Several universities have also set up special offices or technical centers to provide short-term technical assistance to local businesses, including patent searches, technical staff, and other research services. Rather than establishing long-term research agenda, these centers tend to emphasize technology transfer and consulting services. Such centers can be particularly helpful in communities with fragmented industrial bases where firms are unable to pool their resources effectively.

The Center for Industrial Cooperation at the State University of New York at Stony Brook, for example, provides research and technical assistance on specific industry projects for 15 dues-paying industrial affiliates. Another technical center is the George Mason Institute at George Mason University in Virginia, which provides technical assistance to high-technology business and education groups in the State. The Delaware Technical and Community College (with funding from the U.S. Economic Development Administration) is setting up a similar center to work with technology-based businesses in Delaware; the school also is working with General Motors to develop a joint training and retraining program for auto workers. The University of Missouri also is working closely with the auto industry to train and retrain workers for the new technical demands of automated manufacturing. The University of Wisconsin has an Industry Research Program that provides business with information on the results of its research.

Several university/industry research partnerships have been formed to match the special technical needs of high-technology industry and the unique resources of the educational sector. The two most common forms of cooperative ventures are joint ventures between a university and a single firm, and research consortia involving several companies and/or universities. Such arrangements can take many legal forms, including long-term research contracts

Photo credit: George Mason University

George Mason Institute in Virginia

and limited partnerships. Recent Federal legislation enables industrial partners to obtain tax credits for investments in university research, in addition to capital gains treatment for profits on the products of the research.

Cooperative research ventures represent a very small portion of university research, although several substantial ventures have been launched in the last few years. The most visible and substantial agreements have been signed between Harvard University and Monsanto; Washington University and Mallinckrodt; Harvard Medical School and Seagrams; Massachusetts Institute of Technology and Exxon; Carnegie-Mellon and Westinghouse; and Washington University and Monsanto. The relationships vary from simple corporate grants to complex contracts giving the industrial partner control over intellectual products.

The direct grants approach is exemplified by the $6-million, 5-year immunogenetics program sponsored by DuPont at Harvard; the $7-million, 10-year combustion science grant from Exxon to MIT; and the $5-million, 5-year robot development project sponsored by Westinghouse at the Carnegie-Mellon Robotics Institute. These grants are targeted for specific research and have a turn-back arrangement so that the corporation can benefit from inventions.

A few universities, seeing the potential for income from cooperative research, have become entrepreneurial. Stanford University in 1981 created Engenics, a for-profit company to develop large-scale chemical processing techniques, and the Center for Biotechnology, a nonprofit research organization provided with $2 million by the six corporate supporters of Engenics. Stanford holds 30 percent of the equity in Engenics.

Other university programs sponsored by individual firms focus on particular academic problems. For example, IBM has a launched a $50 million program of grants and equipment donations to improve manufacturing engineering, and Exxon sponsors a $16.8-million engineering faculty assistance program to supplement junior faculty salaries.

Recently, several companies have organized into consortia to pool resources for several universities and special programs. For example, the 10 major makers of semiconductors (including Honeywell, Hewlett-Packard, and IBM) have established the Semiconductor Research Cooperative, which will identify generic research needs and work with university research departments.

Research consortia may include either one company and several universities, several companies and one university, or several companies and several universities. An example is the research center at Purdue University in Indiana, jointly sponsored by five corporations, to develop computer prototypes. Similarly, Pennsylvania State University has 20 industrial sponsors for a cooperative program in recombinant-DNA technology. Other examples include the Caltech Silicon Systems Project, Stanford's Center for Integrated Systems, the Polymer Affiliates Program at Drexel University, and (perhaps the most complicated example) the Center for Biotechnology Research.

The Center for Biotechnology Research is sponsored by Engenics Corp. (itself a Stanford spinoff) along with six other companies: Bendix, Elf Technologies, General Foods, Kopvenco, Mead, and MacLaren. Three universities are involved: Stanford, the University of California, and MIT. Resulting patents will be held by the universities, with the center receiving royalties, and the contributing corporations having exclusive rights to the patent licenses. The object of the center is to provide multiyear funding for university research and to enhance the effectiveness and efficiency of basic and applied research. It will also allow universities to benefit from a product's financial success, as well as providing industry with incentives to justify long-term research investments.

Technology transfer, through patenting and licensing, has traditionally been handled by university administrators, but recently this important commercialization function has also been assumed by private nonprofit alumni foundations. Some of these foundations are independent of the university, but all of them rely on university research capability for inventions that can be commercialized.

The Wisconsin Alumni Research Foundation is the largest and oldest university technology-transfer operation. It is a multimillion dollar operation. Its 1929 patent of vitamin D has provided $14 million in license income.

More typical is the University of Virginia Alumni Patent Foundation. Funds for the program were provided initially by the alumni foundation, but subsequent funds were raised from the private sector and from royalty and licensing agreements. Patent income averages between $50,000 and $100,000 per year. The foundation has processed approximately 200 faculty and alumni inventions, working with patent attorneys, arranging for licensing, and identifying market opportunities.

The Washington Research Foundation (WRF), a nonprofit organization established in 1982, seeks to increase Washington State's share of the market in high-technology products and processes. WRF plans to work closely with the State's universities as well as other research centers. A bank loan of up to $1 million has been guaranteed by pledges from individuals, law and accounting firms, and manufacturing establishments.

Human Capital Development

Other initiatives focus on developing the human capital that is needed to exploit these technological innovations. Two important secondary effects of the university/industry collaboration discussed above are: 1) improving science and engineering training, and 2) providing continuing education for those already employed by industry. For many initiatives, however, these are the principal goals. Some universities, for instance, provide student internships in high-technology companies or, in cooperation with State governments and local employers, offer special training or retraining programs for technical workers. Local governments frequently lobby for engineering programs at nearby State colleges or develop special "magnet" high schools or technology-based curricula in their vocational education programs.

Several high-technology companies also contribute funds, equipment, or personnel to upgrade science and mathematics instruction in the local public schools. In other cases, local initiatives focus on creating employment opportunities for engineers or technical workers who might otherwise leave the area because of cutbacks at a nearby research installation.

An OTA survey revealed that about half of all State HTD initiatives involve high-technology training or education programs.[11] Training programs, which made up one-third of those surveyed, often operate through grants to other organizations, and many of these programs have obtained funding from Federal sources. Some States are analyzing the use of customized job training (i.e., specifically tailored to the needs of potential employers) in connection with new Federal efforts under the Job Training Partnership Act of 1982 discussed in chapter 5.

High-technology education programs represented almost one-fourth of the initiatives in the survey States. An example is California's MICRO program, which provides funding for graduate fellowships and faculty research projects, and is supported by matching grants from private industry. Several universities have also established industry internship programs designed to provide students with practical experience in technology-based businesses. Lehigh University in Pennsylvania, for example, has a cooperative master's and Ph.D. program that combines professional work (directed by industry advisors) with study and research conducted at the university. Similar programs exist at Carnegie-Mellon University and the University of Detroit, among others.

A number of local communities have also developed engineering programs at local universities. These initiatives, which can be used to develop a technical work force in technology installation and bootstrap communities, include efforts to create an engineering department at a university that has not had one, add graduate programs, upgrade the overall quality of a program, or attract faculty members with specializations in areas of importance to local industry. Local governments in diluted centers, technology installation centers, and bootstrap communities have also used vocational-technical training initiatives to attract high-technology firms. These initiatives have taken the form of adding specific training programs required by local industry or the development of high-technology "magnet" high schools.

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[11] *State Initiatives Survey*, prepared for OTA by the Research Triangle Institute, Alvin M. Cruze, principal investigator, May 1983.

Business executives—working as individuals, participating on advisory councils, or as members of a business organizations—have also focused their attention on strengthening educational institutions. Corporate practices regarding education can be viewed as initiatives to create the innovations and intellectual infrastructure—the raw materials—they need to survive. Many high-technology firms contribute funds to universities, and several trade associations have issued policy statements encouraging their membership to give at the "2-percent level." For example, the American Electronics Association has set a goal of 2 percent of each member firm's annual research budget to be contributed to universities for supplementing faculty salaries and developing research facilities. The Massachusetts High Technology Council asked its members in January 1982 to raise their level of support for higher education to 2 percent of their annual R&D expenditures. In December 1982, they announced they had met their $15 million goal.

Another method of providing resources is lending personnel whose technical skills can assist educational institutions. High-technology companies such as IBM and Xerox have been leaders in this area, particularly for training programs.

The Harris Corp. operates an extensive program with local junior and senior high schools in Florida. Company personnel give lectures and work with school personnel to promote interest in science and mathematics. Harris' activities are motivated by a desire to retain their present employees (whose children attend these schools) and engender positive attitudes toward technology among high school students (who are potential future employees).

Honeywell is involved in the creation of a new magnet program in a local high school in Minnesota. This program will focus on science and math skills but also will promote a broad skills base. Honeywell has worked with the school system to develop a strategic plan for technical skills development, and the company has contributed funds as well as lending personnel.

Donating equipment represents a comparatively small but growing component of private sector initiatives by high-technology firms. According to Independent Sector, an association representing nonprofit organizations, the value of corporate noncash giving (equipment and materials) was approximately $6 billion in 1983. Deductions created by the Economic Recovery Tax Act of 1982 are expected to increase corporate equipment donations. Corporations also view donating equipment as cultivating a market for their high-technology products.

Entrepreneurship Training and Assistance

A special subset of human capital is entrepreneurship, and many HTD initiatives are designed to provide training, technical and management assistance, and other support needed by those who create new technology-based companies. The OTA census identified 15 State initiatives, undertaken in conjunction with State universities, that were designed in part to equip inventors or entrepreneurs with the skills needed to commercialize emerging technologies. These 15 programs are only a fraction of the training efforts of U.S. colleges and universities: the number of entrepreneurship courses grew from fewer than 10 in 1960 to more than 200 in 1980, and in 1984 as many as 400 colleges and universities offered courses in the creation and management of small businesses.[12] In some cases these programs are supported by the private sector, which sees in them an opportunity to promote the values of capitalism as well as the university's role in technological innovation and business development.

The University of Texas, for example, has not only a Chair of Free Enterprise (established in 1976) but also an Institute for Constructive Capitalism, funded by Mobil, Shell, Tenneco, and other corporations. Similarly, two leading venture capitalists have recently endowed a chair at the Harvard Business School devoted to the creation and management of new business ventures.

Wichita State University established a Center for Entrepreneurship and Small Business Management in 1977. The initiative is supported by over 50 area businesses, and the force behind its creation and development is a professor who is also a successful entrepreneur. In addition to seminars and publications, the Center is about to start a small business incubator.

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[12] "Universities Emerge as an Important Catalyst in the New Business Development Process," *Venture Capital Journal*, vol. 23, No. 8, August 1983, p. 8.

In addition to courses for full-time students, many universities also provide seminars and conferences on business development topics, notably on how to raise venture capital, or provide technical and management assistance to local entrepreneurs and inventors. Baylor and Case Western Reserve, among other universities, provide innovation evaluation programs in addition to courses and seminars. Carnegie-Mellon and the University of Pittsburgh jointly sponsor the Pittsburgh Enterprise Corp. to foster new business development. The MIT Enterprise Forum, sponsored by the alumni association, conducts "incubator forums" in several cities. These efforts have been successful in involving local professionals—lawyers, accountants, bankers, consultants, and government officials, as well as university officials—in the local entrepreneurial network.

One of the most highly developed set of initiatives for promoting high-technology entrepreneurship and small business development has been created by the private sector in Minnesota, in cooperation with the University of Minnesota and State and local governments. StarCo (Start-a-Company), sponsored by the Minnesota Business Partnership, is a program through which established firms assist in the creation of new small businesses through technology spinoff, management consulting, and/or equity investments. Some 35 large corporations have already committed to assist in the startup of two new companies apiece, and smaller firms will assist in the startup of one new company. A related initiative is the Minnesota Project Innovation (MPI), launched in November 1983, which in addition to technology spinoff and entrepreneurship assistance will help the State's small high-technology firms compete for grants under the Federal Government's new Small Business Innovation Research (SBIR) program. MPI, created at the recommendation of the Governor's Commission on SBIR grants and initially funded by a State grant, will be coordinated through and use the resources of the Control Data Business and Technology Center in Minneapolis. Private sector participation in such initiatives is encouraged by State legislation passed in 1983 that provides tax credits for technology transfers or investments in qualified small businesses, as well as for contributions to private sector organizations like StarCo, MPI, the Minnesota Cooperation Office, and the Minnesota Seed Capital Fund.

Financial Assistance

Thirty-four of the 68 State government initiatives surveyed by OTA provide some form of financial assistance to high-technology firms. Most of this assistance is indirect, taking the form of tax credits, industrial revenue bonds, or loan guarantees. While many State programs help firms to locate seed or venture capital, very few provide risk capital themselves.

Most of the local representatives interviewed in the course of the OTA assessment recognized the importance of venture capital to HTD, but few expressed satisfaction with their initiatives to fill this need. Planned and existing efforts included seminars or conferences for venture capital firms and local entrepreneurs, the identification of local venture capital resources, and consulting assistance in procuring venture capital. Several cities, including Cleveland and Cincinnati, were also developing local venture capital funds. However, effective local venture capital programs presuppose a substantial number of high-technology innovations in a community each year, something few communities experience.

Many colleges and universities have begun to take a more active role in financing new technology-based companies.[13] These investments are usually made from the university's endowment or alumni fund, with capital gains rather than new business development as the object. In some cases, universities invest directly in companies that have spun off from research and technical centers. Examples include Boston, Brown, Harvard, Lawrence, and Stanford Universities; the Universities of Chicago, Notre Dame, and Rochester; Rensselaer Polytechnic Institute; and Grinnell College in Iowa. In other cases universities work to make capital available to new starts by investing in venture capital partnerships. About $350 million has been invested in such partnerships, most of it since 1980, by such universities as Harvard, MIT, Stanford, and Yale. Other universities (including Carnegie-Mellon, Georgia Tech, Case Western Reserve, and the University of Pennsylvania's Wharton School) are supporting the formation of local seed capital funds for startups and spinoffs, often in connection with their incubator facilities and entrepreneurship assistance programs.

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[13] Ibid., op. cit., pp. 11-12.

However, formal venture capital is still dominated by independent firms and corporate subsidiaries, which tend to resist geographic requirements. These investments tend to go where the returns are expected to be greatest, which in recent years has meant California and Massachusetts. Several universities and local governments have tried to attract these investments to their areas by holding venture capital conferences. In addition, several State and local governments, in cooperation with local business groups and foundations, have recently established venture capital funds with explicit geographic requirements.

Seed capital, invested at the earlier and riskier stages of a new venture, does tend to stay local, but only about 5 percent of venture activity is targeted for seed efforts, and there are only a few firms—perhaps 5 or 10 nationwide—that specialize in seed investments. One example is the Bay Venture Group, which was established and completed its first deal in 1976. The limited partners are individuals with a net worth in excess of $40 million. They assume that from concept (seed) to public offering will take from 8 to 12 years. Their deals are made on the market promise of "several hundred million dollars" in sales per year. Ideas are found "word of mouth," and the firm provides significant technical assistance. Another, Alpha Fund, is based in Palo Alto and raised $13 million from individuals, corporations, and endowment funds to support seed investments, primarily in the San Francisco Bay Area.

The local economic impact may be even more pronounced for informal seed capital investments. Where there is little local risk capital activity, the private sector has sometimes sought to establish a presence by creating investment vehicles to pool local risk capital and encourage local entrepreneurs:

- The Minnesota Seed Capital Fund was an outgrowth of the Minnesota Business Partnership, a statewide business executives group. The fund has attracted capitalization of $10 million from pension funds and individual investors. It targets its investments instate to firms in the start-up and early development stages. It works closely with the Minnesota Cooperation Office, an independent nonprofit organization that provides technical assistance to new businesses.
- The Michigan Investment Fund (MIF) is a limited partnership that was initiated by the Charles S. Mott Foundation. The Foundation, working with a nonprofit small business expert, developed a blueprint for a limited partnership to serve primarily the economic needs of the State. MIF plans to direct 60 percent of its investment instate, but not all the funds will be invested in high-technology firms. The remaining 40 percent will be used to establish relationships with out-of-State venture firms in hopes that those investments will lead later to capital returning to Michigan. (The Mott Foundation has a blueprint for a similar endeavor that will involve three Michigan counties. Presently in the planning stage, the Flint River Capital Fund will work closely with the General Motors Institute on new technologies.)
- The Cincinnati Chamber of Commerce, with the aid of the Gannett Foundation, is in the planning stage of creating a venture capital firm. The firm will not be required to invest in Cincinnati. The Chamber feels that a local presence will enhance the likelihood of promoting entrepreneurship but will not be directly responsible for generating this capability.
- In Cleveland, the Gund Foundation sponsored a study of the city's economic profile that recommended the creation of three entities—one for research coordination, one for technical assistance, and one to provide local venture capital. The first two are in the planning stage; the Primus Fund has capitalization of $30 million and will start making investments in 1984. These investments will be limited to Ohio, with an emphasis on the greater Cleveland area, and will be targeted for "high-growth" opportunities.

Physical Capital

Local governments often seek to encourage HTD through changes in land use and zoning, as well as the provision of public services and facilities. Research and science parks—parcels of land set aside for research-intensive firms and facilities, with varying tax incentives and eligibility requirements—are the most common form of this type of initiative.

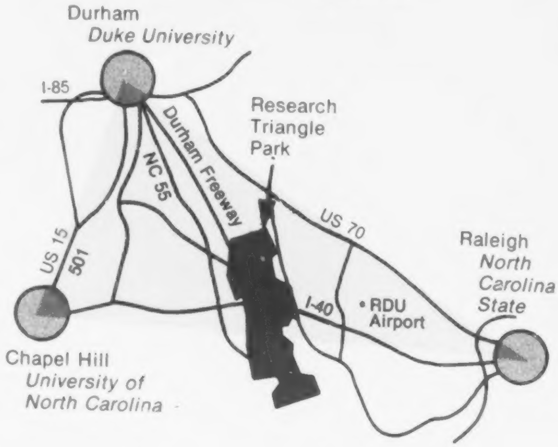
These parks are usually accompanied by improvements in local utilities, transportation systems, and other infrastructure. More than 150 research and science parks have been developed in the United States since the 1950's, and all five types of communities identified earlier have engaged in this type of initiative.

Research and science parks have also been built by universities on sites adjacent to the campus, often in conjunction with entrepreneurship programs or technical centers. Four basic benefits can result from locating a research or science park near a university. First, increased interaction and easier communication between university and industry researchers helps to broaden the mutual understanding of problems and needs. Second, business gains quicker access to new developments through increased information and knowledge transfer. Third, business also gains access to student workers and faculty consultants, as well as to laboratory, computer, library, and other resources. Finally, the increased interaction opens opportunities for creating new businesses and new university/industry programs.

The Stanford Research Park in California is often cited as the model for university/industry science parks, as is the Research Triangle Park in North Carolina, although it was originally a State government initiative. A more recent example of this initiative is at the Washington State University, which recently established a research and industrial park to provide consulting opportunities for faculty, employment opportunities for students, and enhanced research funding for the university. The University of Utah has a science park specializing in biomedical research and development. Rensselaer Polytechnic Institute, a leader in university/industry cooperation, has a new high-technology industrial park 15 minutes from campus. The University of Illinois is working with the State to set up a high-technology research park on land donated by the city of Chicago. Similar efforts are underway in Florida, Michigan, New Jersey, Connecticut, and several other States.

Science and research parks are not without risk, however: they take a long period of time to become successful (often 15 to 30 years); carrying costs can be high if suitable users are not attracted quickly; and the parks can monopolize large tracts of valuable land that might be put to other productive uses.

Research Triangle, NC



Some communities ultimately have had to relax their usage criteria to attract nontechnological users, but once undermined in this manner the research parks lose much of their appeal to technology-based companies. Recent studies suggest that as many as 50 percent of all high-technology parks have failed to achieve their intended goals because of poor planning, insufficient promotion, or lack of ties with nearby universities.[14] Even among parks that were started by or closely affiliated with universities, only 6 out of 27 were clearly successful; 16 to 18 were failures because they had attracted no industry or less than planned, and the remainder were still in some stage of development.[15]

Incubator facilities, which provide low-cost office and laboratory space for entrepreneurs and struggling firms, are another physical capital initiative of local governments. These facilities are most often built in areas where the quantity of high-quality speculative space for small users is limited. Such areas include inner-city portions of diluted centers and smaller communities without a large high-technology base. Incubator facilities require experienced real estate management, and (as with research parks) carrying costs can be high if they are not utilized. In addition, technology-based tenants often require technical and management assistance.

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[14] Charles W. Minshall, *An Overview of Trends in Science and High Technology Parks*, Economics and Policy Analysis Occasional Paper No. 37 (Columbus, OH: Battelle Columbus Laboratories, October 1983), pp. 18-21.

[15] Southern Regional Education Board, *Sites for High Technology Activities*, draft based on report by Battelle Institute, June 1983.

Several universities also have established incubator facilities to make their resources available to new businesses or entrepreneurs developing a new product or process. Such a center recognizes and formalizes the university's role as a seedbed for new technologies and new technology-based companies. This approach incorporates and exploits several resources of the university, including low-cost office and laboratory space, as well as access to capital, business planning, and management advice from faculty members and local professionals. While some of these centers extend eligibility to qualifying small business, their emphasis is on the enterprising student or faculty member who needs a start in commercializing a promising innovation.

The oldest such facility is the University City Science Center in Philadelphia, founded by 23 colleges and universities in 1967, but similar centers exist at Rensselaer Polytechnic Institute, Georgia Tech, Carnegie-Mellon, MIT, Wichita State, and the University of Missouri. The Utah Innovation Center, set up by the University with an NSF grant in 1978, has continued as a private concern following the loss of its Federal funding. (See ch. 5 for a discussion of the NSF Innovation Center Experiment.)

Moreover, recent data on the role that small business plays in innovation and job creation have sparked interest within the private sector regarding incubator facilities and technical assistance centers. These facilities often provide technical and financial assistance as well as low-cost office and laboratory space for high-technology firms in the seed and startup stages.

For example, the Advanced Technology Development Center at the Georgia Institute of Technology is a new effort to promote indigenous high-technology industry in the Atlanta area. The effort is State-initiated, but the private sector will contribute $1.7 million of the projected $5.1-million budget. Facilities now under construction will provide low-cost space for entrepreneurs. As of 1982, the Cen-

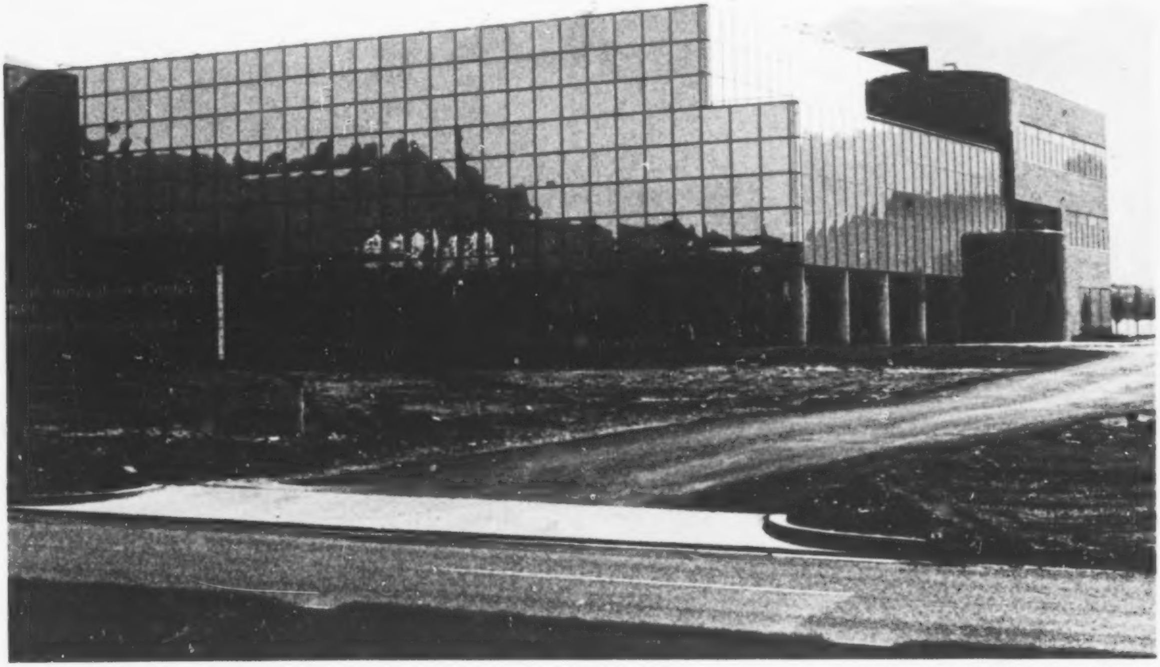

Photo credit: Utah Innovation Center

Utah Innovation Center, Phase I

ter had worked with 30 companies. One of its most successful programs is an annual venture capital conference that brings together startup hopefuls with potential investors.

Control Data Corp.'s Business and Technology Centers (BTCs) approach the need for incubators as a profit-making opportunity. BTCs provide entrepreneurial firms with technical assistance and basic shared services at reasonable rates. The original Control Data BTC, established in St. Paul in 1979, has been highly effective in promoting the survival and growth of small entrepreneurial firms: out of 126 new companies representing over 1,000 new jobs, the survival rate is 88 percent over the first 5 years. BTCs have already been established in 12 other U.S. cities, and Control Data plans to open as many as 13 additional BTCs during 1984.

Information Gathering and Dissemination

The first step in almost any State or local high-technology strategy is the creation of a task force or commission, usually with university and private sector participation. Task forces serve to focus local attention and often have a pronounced networking effect. They also perform a valuable service in gathering information about the needs and problems that can be addressed through HTD; the institutional and economic resources that can be brought to bear; the kinds of actions that might be undertaken; and the experience of other States and communities with similar initiatives.

OTA identified several instances in which task force recommendations were the basis for subsequent State initiatives, and in some cases the task force itself became a permanent council or foundation charged with implementing and overseeing these activities. Examples include the Connecticut Product Development Corp., created in 1972 by legislation growing out of the State's Full Employment Task Force; Georgia's Advanced Technology Development Center, created as a result of a study commissioned by the Governor in 1979; the Bay State Skills Corp., which evolved from a gubernatorial plan to meet Massachusetts' need for more skilled and trained workers; and the Tennessee Technology Foundation, created as a result of recommendations of the Governor's Technology Corridor Task Force.

Local task forces usually are appointed by mayors, although they are sometimes an adjunct of the chamber of commerce. They generally include representatives from industry, education, and government. They are distinct from other initiatives in that they are not designed to overcome some limitation in a community's ability to attract or retain high-technology companies. Instead, they have a designing function and, in some cases, participate in implementation. They also have a pronounced networking effect and serve to focus local attention and resources on high-technology economic development.

High-technology information dissemination usually takes the form of government marketing programs aimed at target firms and industries. The OTA census found that the services most frequently offered by dedicated State programs involve information dissemination—17 programs link industry and university resources, and 8 others involve promotional activities aimed at high-technology prospects, in part to inform them of the existing HTD resources and activities in the State. These initiatives often involve extensive cooperation with individual communities.

At the local level, virtually all communities conduct marketing programs to attract new industry. However, those localities with the most sophisticated programs directed at high-technology companies tend to be those that already have experienced the greatest success in attracting them. These include communities in all categories, with the exception of the high-technology centers themselves, but the programs differ in their focus depending on the type of community involved. For example, the spillover communities are most likely to direct their efforts toward companies located in the city to which they are adjacent, while bootstrap communities primarily seek to attract branch plants of expanding technology-based companies. The key ingredients of these initiatives are the identification of specific firms for which the community would have the greatest appeal, the improvements to the required infrastructure or amenities, and a concerted marketing effort through mail, telephone, and personal visits.

Business groups also undertake promotional campaigns, usually advocating desired changes in public policy but occasionally aimed at increasing the development efforts of member firms. These advocacy programs build consensus and bring private prestige to bear on public problems, just as public advocacy programs give recognition to the contributions of business groups and individuals. National trade associations tend to focus on Federal policy, although as the locus of governmental responsibility for economic development shifts to State and local governments, State business groups can be expected to gain in influence.

The Massachusetts High Technology Council (MHTC) is one of most successful business/civic advocacy organizations in the Nation. In 1979, the Council established a "social contract" with the Massachusetts government to create 60,000 jobs if the State brought total taxes to a level competitive with the 17 other States against which local high-technology firms competed for technical talent. Taxes have dropped, and MHTC has fulfilled its part of the contract.

Additional Factors

Whether the initiatives investigated by OTA hold promise for promoting both technological innovation and regional economic development is unclear. Most have been launched in the past 3 to 5 years, and the majority have undergone no formal evaluation or comparative analysis. Moreover, given the differences in their goals and mechanisms, absolute criteria for success will be difficult to determine—some are designed to attract new industry in the short run, while others are building the technological infrastructure for growth in the future. Many involve institutional changes that might take decades to bear fruit.

In fact, since their most important effects may be indirect, the effectiveness of these initiatives will always be difficult to measure. In some cases, relatively mature initiatives have been very slow to produce any significant results, while more recent programs elsewhere are already considered successful. Furthermore, many of the States and communities investigated by OTA had already experienced a considerable amount of HTD before launching their initiatives, and other regions have experienced a great deal of HTD even without a dedicated initiative.

No single factor explains why some communities and regions have been more successful than others in nurturing and benefiting from HTD. For every locational determinant identified in economic theory or implicit in government practice, examples can be provided of cities that have several or all of the ingredients but have not yet achieved success. The traditional factors—strong research university, skilled labor pool, available financing, the presence of corporate headquarters, transportation, good climate, and cultural amenities—may not always be enough. OTA's investigation suggests that the following additional factors may also be important for State and local HTD initiatives:

- identifying local needs and resources;
- adapting to external constraints;
- local initiative and partnership;
- linkage with broader development efforts; and
- sustained effort, often over a period of decades.

In short, it appears that cooperation and commitment by public and private individuals and organizations may provide the necessary catalyst to bring the ingredients together.

Identifying Local Needs and Resources

Successful HTD initiatives generally reflect a sense of the region's distinctive attributes and potential. Different regions have different needs and different resources with which to address them. As a result, no single approach or program design will work in all settings. Although individual States and communities can learn from the successes of others, implementation must be region-specific. This requires a detailed knowledge of local conditions and a clear recognition of the local attributes, both strengths and weaknesses, that will influence a region's ability to attract or spawn high-technology industry.

Analysis of this type is typically conducted by high-technology task forces representing government, university, and industry. In some cases, this function has been performed by economic development officials or by outside consultants. In any case, successful initiatives have required careful planning, and some of them have been based on comprehensive, long-term master plans. At the minimum, the analysis should identify explicitly, in advance, not only what the community can realistically expect to achieve through HTD, but also the resources that will be required to achieve these goals.

In many cases, successful initiatives simply redirect or build on preexisting resources and activities, often by creating new institutional linkages. The increased emphasis on the roles of universities and entrepreneurs, for example, reflects a recognition that they constitute an important and possibly underutilized resource for regional economic development. Similarly, most State initiatives reflect an awareness of the existing industrial base and the role it plays as both the source of technological opportunities and a potential market for new products and processes.

Adapting to External Constraints

There are many factors over which a community has little control. These include physical factors such as climate, terrain, and proximity to existing high-technology centers, as well as a variety of policies and regulations imposed by higher levels of government. Successful States and communities recognize these external constraints and adjust their objectives and strategies accordingly. By doing so they also avoid the conflicting goals and inflated expectations that might otherwise lead to constraints within the community.

Those without an existing high-technology base, for example, typically focus their initial marketing efforts on branch plants rather than on research- or technology-intensive establishments. Over time, as these branch plants create a skilled labor force and technical infrastructure, the communities may be able to attract more sophisticated operations and encourage local spinoffs. The time required for this process is another constraint. Even when initiatives are successful, HTD does not represent a quick fix for regional economic problems. In addition, no successful State or community focuses its efforts exclusively on these industries; most HTD initiatives are components of a broader economic development strategy.

Local Initiative and Partnership

High-technology development efforts have generally been most successful when they are initiated and implemented locally. Some communities receive substantial help from State governments in developing university resources and complementing the local marketing program. Others have found innovative uses for funding and development tools made available by the Federal Government. But in most cases, the objectives and strategies are developed locally, and local representatives play a major role in the design and implementation of the initiatives.

While the organization responsible for the program or the degree of collaboration may vary between initiatives or communities, institutional collaboration is almost always present in successful initiatives. In fact, the form the initiative takes may be less important than the reordering of institutional relations it engenders. This cooperation or "partnership" among government, universities, and local business groups emerges most easily at the local level, where the public and private sectors are less distinct.

Stable political climate and local government with an efficient, pro-business image have a positive influence on the level of institutional involvement and cooperation. So too does the existence of organizational mechanisms or a network of intermediaries and brokers to bring together public and private leaders. Also important is the past history of public/private initiatives in the community: a strong history of collaborative efforts provides a foundation of positive experience, as well as building trust and understanding between business, government, and community groups. States and communities that have benefited most from these factors have three characteristics in common:

- A social and organizational culture that promotes an *underlying consensus*—a common civic perspective and a positive attitude about the region's attributes and prospects.
- An environment that nurtures *entrepreneurial leaders, both public and private,* who combine an established track record for innovation, a broad view of their community's promise, and the ability to recognize and exploit changing opportunities.
- A network of *business/civic advocacy organizations* that attracts the membership of top officers of major companies and receives from

them the commitment of time and effort to work on issues of mutual concern, including cooperation with the public sector.

Linkage With Broader Development Efforts

Successful high-technology initiatives are seldom undertaken in isolation, and the most substantial results often come from multiple initiatives and those that are components of a broader development strategy. This requires complementarity between HTD programs and more traditional economic development activities, as well as coordination between the HTD initiatives of different sectors. This restructuring of institutional relationships, aimed at mobilizing the technological infrastructure for HTD, is in fact the principal difference between HTD and general economic development initiatives.

Most State officials consider their high-technology initiatives to be a logical and perhaps inevitable extension of more traditional economic development efforts. This attitude apparently is correct—the majority of high-technology executives who stated that their location decisions had been influenced by a State program identified a general economic development or training program, rather than a high-technology initiative. Efforts to attract high-technology branch plants, for example, are generally part of a broader effort to strengthen or diversify the industrial base. Similarly, most local strategies involve not only incubator facilities and technical centers but also more traditional initiatives to make the community more attractive to technology-based firms, such as training programs, educational improvements, or the construction of a cultural center. Likewise, efforts to increase local venture capital activity are usually tied to university improvements, entrepreneurship assistance, and technical extension services. The failure to create such linkages between university and industry was a leading cause of failures in science and research parks.[16]

The same may be true of the role of Federal programs in State and local HTD initiatives. Block grants and tax-free bonds are highly flexible instruments and have been used for a wide variety of projects, depending on the needs (or desires) of different communities. Their influence is usually indirect and diffuse: they provide funds and development tools that can be very effective when used imaginatively, in conjunction with other efforts, by entrepreneurial local leaders.

Sustained Effort

HTD does not represent a quick fix for regional economic problems, and few States or communities have developed large concentrations of high-technology establishments in a short period of time. Route 128 and Research Triangle Park, for instance, might have been considered failures if their results had been measured too soon. Based on the few initiatives that have been in place for a significant period, a minimum of 10 or even 20 years may be required to translate these institutional innovations into a significant number of local firms and jobs that can be attributed to products created by indigenous entrepreneurs or research establishments. As a result, success will depend in part on sustained effort and commitment, including stable long-term funding.

Different initiatives have different time horizons, however. Some regions have been able to strengthen their economies quickly by attracting branch plants of technology-based companies. More immediate benefits can be achieved through short- and medium-term strategies, such as administrative reforms and infrastructure improvements that lay the foundation for subsequent private investment. Educational and venture capital initiatives, on the other hand, take longer to show results. This suggests the possibility of a staged, incremental approach to HTD in which different organizations launch complementary initiatives with different time horizons that build on one another. The exact timing and mix of mechanisms in such a strategy are subjects for further research.

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[16] Minshall, op. cit.

CHAPTER 5

The Federal Role in Regional High-Technology Development

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CHAPTER 5

The Federal Role in Regional High-Technology Development

Introduction

Fiscal, monetary, and other broad Federal policies influence the general economic climate for State and local development efforts, just as they affect the environment for all economic activities. In addition, Federal policies have had important impacts on regional high-technology development (HTD) *when existing Federal programs or resources were utilized in conjunction with a State or local HTD initiative.* In some cases the Government's role was relatively direct: Federal officials served as members of task forces and commissions in several communities, and other initiatives were supported by Federal planning grants. More frequently, however, the Federal role has been an indirect or even unintentional result of the pursuit of an agency's primary mission.

Major Federal research and development (R&D) installations, for example, frequently have provided the base or nucleus around which high-technology initiatives have been built. In addition, many State and local initiatives have made innovative use of block grants, training programs, loan funds, and other development tools provided by the Federal Government. These Federal programs provide highly flexible instruments that have been used for a wide variety of projects, depending on the needs of different communities. They were not specifically designed to assist in regional HTD, but they have nevertheless proven to be an effective adjunct to regional HTD efforts when used imaginatively, and in conjunction with other efforts, by entrepreneurial local leaders.

OTA's investigation has identified four different roles or areas in which the Government influences regional HTD. The first of these roles is very broad in nature:

- *policies to encourage R&D and technological innovation,* including not only Federal investments in R&D and tax incentives for private investments in innovation, but also macroeconomic and trade policies and regulatory policies in the areas of patents and antitrust.

These basic national policies exert a profound influence on the economic environment for all business activity, especially technological innovation. However, the broad impacts of the policies are beyond the scope of this assessment. They are discussed briefly below, but more attention will be given to three other roles in which the regional impacts of Federal policies and programs are more direct and more easily identified:

- *technology transfer programs* that attempt to increase innovation and growth of industrial sectors by encouraging the diffusion and utilization of federally developed technologies by private industry;
- *general regional development programs,* including block grants and technical assistance, which provide flexible funding tools that have been put to innovative uses in many State and local HTD programs; and
- *planning and demonstration projects* that facilitate new institutional linkages and encourage or support the creation of new HTD mechanisms at the State and local levels, some of which have been continued or copied elsewhere with little additional Federal support or intervention.

The following sections discuss the nature of these Federal roles and provide examples of programs whose activities have influenced regional HTD or supported State and local HTD initiatives. Recent changes in these policies, and proposed changes embodied in pending legislation, are also discussed.

R&D and Innovation Policies

The Federal Government encourages R&D and technological innovation through two activities: funding R&D directly, and creating an economic climate conducive to private investment in R&D and innovation.[1] Direct funding of R&D is usually justified in terms of *public goods*, for which the Government is the principal customer, or *social returns* from basic research in which the private sector is likely to underinvest. However, private firms are the major actors in the commercialization and diffusion of new technologies, and the Government also encourages technological innovation through policies that make private R&D investments more attractive. These policies are directed at the U.S. economy as a whole, rather than the needs of particular industrial sectors or geographical regions, and identifying their impacts on regional HTD is beyond the scope of this assessment. Nevertheless, their general influence on regional HTD may be greater than that of any specific program discussed in this chapter.

Direct funding represents the most visible Government role in encouraging R&D and innovation. In recent years the Federal Government has funded about half of the R&D conducted in the United States, most of it for public goods related to the missions of particular agencies. National defense is the archetypal public good, and defense-related spending claims an increasingly large share of the Federal R&D budget—from 48 percent in 1980 to 70 percent in the fiscal year 1984 budget request, the highest defense share since 1962 (see figs. 5 and 6). Defense-related R&D is heavily oriented toward development activities (over 80 percent) and is concentrated primarily in the aerospace and electronics industries. Commercial spinoffs from defense R&D have benefited the semiconductor and computer industries in Silicon Valley and Route 128, but these civilian applications are long-term, and unpredictable, and tend to be minor relative to the Federal R&D investment in public goods.[2]

Direct funding of R&D also provides social returns in areas where private industry is likely to underinvest, particularly long-term basic research in which the risks are high and the private returns smaller than the social returns. Universities carry out over half of the basic research conducted in the United States, and funding university research is also an aspect of the Government's educational responsibilities. A major trend in recent civilian R&D budgets has been a sharp shift away from development and toward basic research, reflecting the Administration's belief that applied R&D should be left to the private sector. Applied research funding has changed little in recent R&D budgets, despite its key role in transforming laboratory research into commercial products and processes.[3] This trend may be partially offset by increases in private sector applied research, often in collaboration with universities.

In addition to direct funding, the Federal Government also promotes innovation through policies that encourage increased private sector investment in R&D and new technologies. Fiscal, monetary, regulatory, procurement, and trade policies—all have indirect effects that, collectively, may have more influence on technological innovation and regional HTD than programs specifically targeted on R&D.[4] Changes in tax policy with regard to capital gains and in regulations affecting pension fund investments, for example, contributed to a tripling of the formal venture capital pool between 1978 and 1983. The regional impacts of this increase have been mixed: while investments have increased in most regions, venture capital activity remains concentrated in a few States, and it is unclear whether there has been a corresponding increase in local seed capital activity.

Recent changes in tax policy, notably the Economic Recovery Tax Act of 1981 (ERTA), have also increased the attractiveness of investment in new plants and equipment, thereby speeding the diffu-

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[1] The following material is based in large part on Louis Schorsch, *Federal Support for R&D and Innovation* (Washington, DC: U.S. Congressional Budget Office, April 1984).

[2] Ibid., p. 11; see also the OTA staff memorandum, *Development and Diffusion of Commercial Technologies: Should the Federal Government Redefine Its Role?* March 1984.

[3] Schorsch, op. cit., p. 52.

[4] For a general overview of this subject, see Elliot Schwartz, *The Industrial Policy Debate* (Washington, DC: U.S. Congressional Budget Office, December 1983); and Philip Webre, *Federal Support of U.S. Business* (Washington, DC: Congressional Budget Office, January 1984).

Figure 5.—Federal, Private, and Total R&D, 1953-84

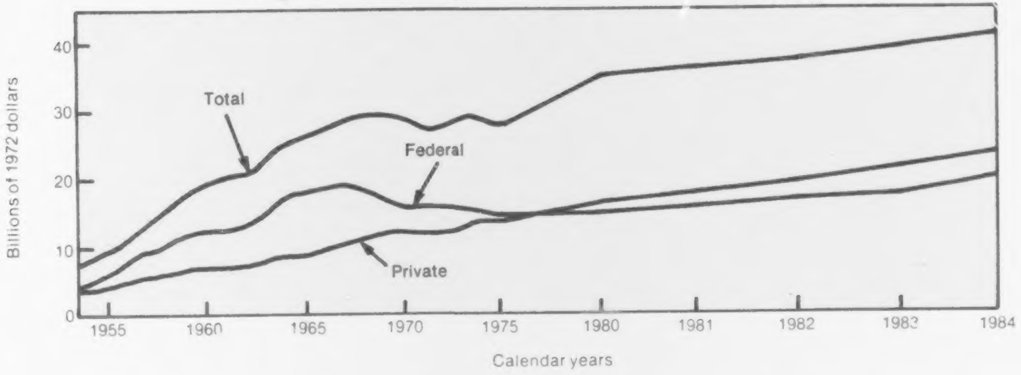
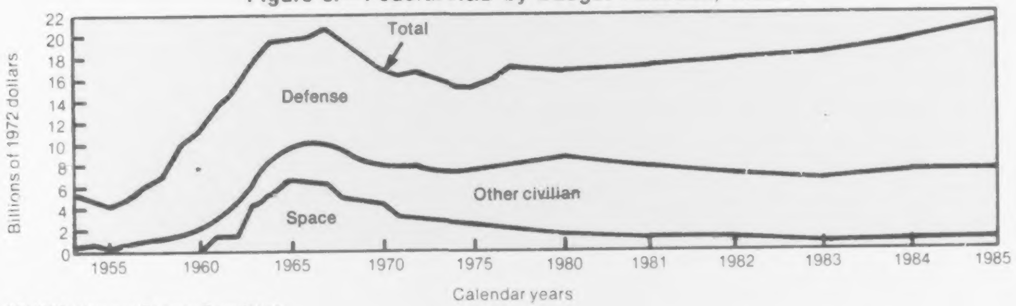


Figure 6.—Federal R&D by Budget Function, 1953-85



SOURCE: National Science Foundation

sion of new process technologies. ERTA also increased the incentives for equipment donations to universities, which figured prominently in many of the university/industry initiatives investigated by OTA, and instituted a 25-percent incremental tax credit for increased R&D expenditures. Private sector investment in R&D has in fact accelerated since the late 1970's, but this trend predates the recent changes in macroeconomic policy. Its causes probably lie in industry's belief in the importance of R&D for international competitiveness.[5]

A recent analysis by the Congressional Budget Office (CBO) suggests that the overall impact of R&D incentives has been relatively small but that, with some specific changes, the incremental tax credit might usefully be extended beyond its scheduled termination at the end of 1985.[6] Similarly, some reconsideration of antitrust enforcement might be desirable, particularly with regard to joint R&D ventures, but such changes should be carefully evaluated to determine their effect on competition, as well as their technological impacts.[7] These new institutional linkages are key components in several of the regional HTD initiatives described in chapter 4.

Debate on national R&D and innovation policies is seldom concerned with regional HTD efforts, but Federal R&D does have differential effects on regional economies through patterns of high-technology procurement, the distribution of university R&D expenditures, and the location of Federal R&D facilities. Government procurement can provide a large stable demand, establish pilot production facilities, or set design and performance standards that require the use of new technologies.

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[5] Schorsch, op. cit., pp. 52, 69-70, 74-75.

[6] Ibid., pp. 72-73, 76-83, 96-97.

[7] Ibid., pp. 83-85, 97-98.

For example, the Department of Defense (DOD) contributed to the growth of high-technology complexes in Silicon Valley and Route 128 by concentrating research and procurement contracts there during the 1950's. These practices have also been used by DOD to promote the machine tool industry during the 1970's and the robotics and super computer industries during the 1980's. Similar practices also promoted the development of new energy technologies in the 1970's. However, CBO has found little evidence that procurement can play the same role in civilian technologies where the Government does not dominate the market.[8]

State and local groups have little control over procurement patterns and are more likely to lay the foundations for regional HTD through university improvements that attract additional Federal research funding. Indeed, many of the university research institutes investigated by OTA derive a large share of their operating budgets from Federal research contracts. As civilian R&D shifts from applied to basic research, however, it has become increasingly important that universities also strengthen their ties with industry, in order to generate technologies with local business and employment potential.

The location of Federal R&D laboratories and engineering facilities can have a major effect on local economies, though not necessarily on HTD, by bringing jobs and technically trained personnel to a community. MIT's Lincoln Lab, for example, played a large role in the initial development of high-technology industry in the Boston area, just as Oak Ridge has contributed to HTD in eastern Tennessee and NASA's Marshall Space Flight Center to that of Huntsville, AL. The Environmental Protection Agency became the largest employer in North Carolina's Research Triangle Park, and helped to ensure the Park's success, when it decided to locate its 1,500-employee Research Center there in 1965. Other Federal R&D facilities, however, have had only a slight impact on local economies. Many were located in remote areas for security reasons, and others never developed active linkages with local universities and businesses. While these Federal installations may provide a valuable resource on which State and local initiatives can build, their contribution to regional development really depends on how active they are in transferring new technologies to private firms.

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[8] Ibid., pp. 86-87

Technology Transfer Programs

Except for the few instances where industrial development is regarded as a national security concern, the Federal Government most directly stimulates technological innovation in private industry through technology transfer programs, which make available the results of federally funded R&D or support their application. Funds spent on disseminating knowledge gained through Federal R&D are considerably smaller than the amounts expended to gain that information, as one would expect. The fruits of technology transfer are beneficial to the national economy, but the precise benefits have been difficult to quantify and it is difficult to say how important technology transfer is to regional HTD. These programs are nationwide, so their regional impacts are determined by the extent to which they are used by firms in one area.

However, Federal technology transfer programs are more likely to contribute to regional HTD than are Federal R&D programs, for two reasons. First, the more than 700 Federal laboratories and technology development centers are located throughout the Nation, in communities both large and small, urban and rural. To the extent that technology transfer takes place on a decentralized basis, therefore, Federal R&D facilities can become a vital component in the technological infrastructure of the areas in which they are located. Second, many of the HTD initiatives launched by State and local governments and universities focus on technology transfer and improved linkages between academic research and industrial application. As a result, these State and local mechanisms are in a better position to act as a clearinghouse or broker for information about Federal technologies and access to Federal personnel.

OTA has identified three general modes of Federal technology transfer, as well as numerous examples of successful interaction between Federal, State, and local efforts. With regard to direct technology transfer, the three typical approaches have been:

- *technical information,* usually in the form of newsletters, directories, or computer data bases that list Federal technologies available for licensing and use by private firms;
- *technology brokering* by agency staffs, who either seek out potential users of existing federally owned technologies, or provide referral services for inventors seeking technical or financial resources; and
- *technical extension services,* which provide consultants to assist firms in solving technical problems in a certain field of specialization.

A fourth form of technology is *engineering demonstration,* in which an agency takes the responsibility for demonstrating the feasibility and commercial potential of a new technology. Demonstration projects have been most common in defense- and energy-related industries; they have less general potential for promoting regional HTD based on civilian or consumer technologies.

Technical Information

The main effort of technical information services is the dissemination of research results, usually in printed form. For example, the Department of Interior's Bureau of Mines issues a newsletter; NASA publishes selected abstracts of technologies and a selection of useful computer programs; and DOD has a single facility (the Defense Technical Information Service) that holds all the technical abstracts its contractors or potential contractors might need. The largest data base of this type is maintained by the Department of Commerce's National Technical Information Service (NTIS), which catalogs most of the federally funded technology available for licensing by the private sector.[9] Each agency serves different clients and provides different services, usually as a result of the agency's mission. In most cases, however, technology has been transferred primarily to industry, rather than to State and local governments. In addition, the transfer function has been essentially passive—the information is available to all comers, but it is up to the user to identify those with commercial potential.

A major change is being brought about by the creation of a Center for Utilization of Federal Technologies (CUFT) in NTIS and Offices of Research and Technological Application (ORTAs) in Federal laboratories, both of which were mandated by the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480). While still founded on the idea that the simple communication of technical information will lead to commercialization, CUFT and the various ORTAs also involve an explicit commitment to *technology evaluation*—active attempts to identify and assess R&D projects with potential application to the needs of State and local government or the private sector. CUFT serves as a central clearinghouse for this information and for subsequent licensing activities. CUFT also helps State and local governments to identify both a product or process they need and a manufacturer that will develop and/or package it for the governments to buy. CUFT also notifies small business associations and State innovation groups of the availability of Federal laboratory technology.[10]

Technology Brokering

Technology brokering programs differ from technical information programs primarily in providing direct contact between Government researchers and industrial end-users of federally developed technologies. When agencies broker technologies, they actively seek out potential users of federally developed technologies or provide such technologies in response to problems posed by industry. Technology brokering is thus more effective at transferring technologies than are passive technical information services, but the additional cost of providing one-to-one assistance to firms also makes it much more expensive.

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[9] As many as 35 other agencies support technology transfer programs that center on the dissemination of information, including the following:

- **National Oceanic and Atmospheric Administration;**
- **Department of Energy** Technical Information Centers;
- **Department of Agriculture** Cooperative Extension Service, Technical Information Systems, Patent Licenses Program, and Science and Education Administration; and
- **Department of Transportation** Technology Sharing Program (which concentrates on disseminating transportation technologies to State and local governments).

[10] *The Stevenson-Wydler Technology Innovation Act of 1980: A Report to the President and the Congress* (Washington, DC: U.S. Department of Commerce, February 1984), pp. 20-26.

NASA's Technology Utilization (TU) program is one of the best known of this type. Initiated in 1962 to bring new aerospace technologies to the attention of American industry, TU's first efforts were in the publishing and distribution of NASA R&D results. By the mid-1960's, TU staffers had found that the availability of technical information alone would not transfer technologies effectively, so they began a process called "people interaction"—matching potential users to information and skills at NASA installations.[11] In 1971, NASA became even more active in technology brokering through *technology adaptation,* the re-engineering of NASA technology for other uses, such as a firefighter breathing system based on spacesuit technology.

Another part of the TU program with particular relevance to regional HTD initiatives is NASA's nine Industrial Applications Centers. All are located at universities, where they offer information services, workshops, and technical assistance to industrial clients, most of which are small manufacturing firms. Fees cover about half the cost of these centers; NASA's subsidy averages about 28 percent, with the balance coming from university funds. In Florida and Kentucky, the State governments match the NASA subsidy for their centers in exchange for exclusive assistance to businesses located in those States.[12]

Extension Services

Extension services are distinguished from technology brokering by their decentralized structure and interactive operation. They provide much the same services as technology brokers, actively seeking out potential users of publicly owned technologies and providing technical solutions to questions posed by client firms. But most technical extension services are based at State universities and colleges, rather than at a few Federal facilities, resulting in closer and more widespread linkages with regional economies. In addition, they have an interactive relation with their clients: extension services not only respond to client requests, but also try to convince firms to adopt technologies that will increase productivity.

The most extensive, best known, and probably most successful of these is the Cooperative Extension Service of the U.S. Department of Agriculture (USDA), founded in 1911, which is part of an integrated national system of agricultural research, development, and technology transfer that traces its origins to the Morrill Act of 1862. Recent attention to the needs of technologically advanced manufacturing has led to proposals for a Federal extension service modeled after USDA's. While technical extension to manufacturers may work, however, the model of agricultural extension may be faulty.

Both NASA's TU program and the State Technical Services (STS) program have been compared to USDA's extension efforts, usually unfavorably. To some extent the relative lack of success in nonagricultural technical extension has been due to underfunding—NASA's entire technology transfer budget was $9 million in fiscal year 1983, and STS expended less than $11 million during its 1965-69 lifetime, while USDA's extension budget was $334 million in fiscal year 1984 alone.

However, differences in scale may be less important than differences in the nature of the technologies, user groups, and markets that are involved. Technical assistance to manufacturers requires an added effort to adapt existing technologies to specific applications because of the diversity of manufacturing firms.[13]

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[11] James J. Haggerty, *SPINOFF 1983* (Washington, DC: National Aeronautics and Space Administration, Technology Utilization and Industry Affairs Division, May 1983), pp. 134-135. Two programs not mentioned in the presentation seem to fit into this category. The Corporate Associates Program is a joint effort of NASA and the American Institute of Aeronautics and Astronautics, whereby the AIAA introduces nonaerospace firms to NASA, its technologists, and its activities. The Technical/R&D Exchange Agreements program exposes firms to NASA activities, and NASA/TU offices to firms, through personnel exchanges.

[12] Paul Brockman, Ray Whitten, and Leonard Ault, presentation to the Federal Interagency Coordinating Group of the Federal Laboratory Consortium, Dec. 12, 1983.

[13] Everett M. Rogers, J. D. Eveland, and Alden S. Bean, *Extending the Agricultural Extension Model,* Institute for Communication Research, Stanford University, September 1976, NSF contract No. 75-SP-0265, p. 117; see also William A. Hetzner, Louis G. Tornatzky, and Katherine Klein, "Manufacturing Technology in the 1980's: A Survey of Federal Programs and Practices," *Management Science,* vol. 29, No. 8, August 1983, pp. 951-961.

In addition, technical problems are not the principal cause of failure for manufacturing innovations. Research has shown that new products from small, high-technology firms are more likely to fail because of inadequate management, unfavorable markets, or both.[14] This suggests that entrepreneurship assistance, of the sort already provided by many State and local HTD initiatives, may be more effective than technical assistance from the Federal Government.

Recent Policy Developments

When Congress required NASA to disseminate the as-yet-unknown benefits of space exploration (National Aeronautics and Space Act of 1958, Public Law 85-568, sec. 203), it became the first and, until 1980, the only Federal agency explicitly required to engage in technology transfer. In the past decade, however, there has been increasing congressional attention to technology transfer. Congress first addressed the issue of Government patent policy after research showed that only 5 percent of federally owned patents were ever commercialized, compared with 33 percent of university patents.[15] Congress passed the Patent and Trademark Amendments of 1980 (Public Law 96-517), which allowed small businesses, universities, and nonprofit research institutes to retain title to discoveries made under Government contract. Legislation was introduced but not passed by the 97th Congress that would apply these rights to all Federal contractors. Patent rights were extended to all Federal contractors by Presidential Memorandum on February 18, 1983, and bills to make this extension law have again been introduced in the 98th Congress: the Uniform Patent Procedures Acts (S. 2171 and H.R. 4964).

Patent rights for extramural inventions made with Federal assistance represent a relatively minor facet of technology transfer, however. Before Public Law 96-517 was signed into law, the Federal Government received less than 8 percent of the more than 70,000 domestic patents granted each year.[16] Of broader public policy importance is the transfer of the results of Federal intramural R&D to industry. A formal Federal laboratory role in technology transfer coalesced in 1974 with the formation of the Federal Laboratory Consortium, a voluntary association of technology transfer officers. Among the over 700 Federal research installations, however, technology transfer efforts varied widely. Especially within the numerous DOD labs, prominence of technology transfer depended on its position on an individual administrator's or organization's agenda.

Congress acted to standardize this role with the passage of the Stevenson-Wydler Technology Innovation Act of 1980 (Public Law 96-480). It was designed to establish a national policy to enhance technological and industrial innovation by stimulating technology transfer and encouraging the development and diffusion of industrial technologies. It incorporated several suggestions from President Carter's Industrial Innovation Message of October 1979, including the creation of CUFT to coordinate the dissemination of all intramural R&D results. Among its other provisions, Public Law 96-480 required federally funded laboratories to establish ORTAs; to set aside 0.5 percent of their R&D budgets for technology transfer activities; and to assign a full-time staff person in laboratories with annual budgets over $20 million (sec. 11). It also called for the creation by the Department of Commerce (DOC) and the National Science Foundation (NSF) of Centers of Industrial Technology (CITs), to pursue generic technologies and promote linkages between university and industry (secs. 6, 7, and 8); and for the establishment of a program for exchange of scientific personnel between universities, industries, and Federal laboratories (sec. 13).

Recent evaluations indicate that Federal agencies are implementing some but not all provisions of Public Law 96-480. A recent survey by GAO found that most Federal laboratories are covered by an ORTA, and that the agencies surveyed have spent the required 0.5-percent set-aside for technology transfer—an estimated $177 million in fiscal year 1982.[17] GAO did not evaluate the effectiveness of section 11 in enhancing technology transfer, but its survey reveals several features of agency implementation that might constrain the Act's contribution to regional HTD by restricting both the scope and the degree of interaction with State and local initiatives:

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[14] Sumner Myers and Eldon E. Sweezy, "Why Innovations Fail," *Technology Review*, vol. 80, No. 6, March/April 1978, p. 41.

[15] William Boseman, *Government Patent Policy: The Ownership of Inventions Resulting From Federally Funded R&D* (Washington, DC: U.S. Library of Congress, Congressional Research Service, April 1984), IB-78057. See also U.S. Department of Commerce, op. cit., p. 6.

[16] See Gerald G. Udell (ed.), "Implications of the Innovation Process for Public Policy to Stimulate Technological Innovation," in *The Oregon Innovation Center Experiment: 1973-1978* (Eugene, OR: University of Oregon, December 1980), vol. 3, p. 26.

[17] *Federal Agencies' Actions to Implement Section 11 of the Stevenson-Wydler Technology Innovation Act of 1980* (Washington, DC: U.S. Government Accounting Office, forthcoming), GAO/RDED-84-60.

- Four agencies collectively representing 85 percent of the Federal R&D budget—DOD, NASA, DOE, and NSF—have requested waivers of the staffing requirement, primarily because ORTAs would duplicate existing technology transfer activities.
- Although laboratories with an ORTA show a higher level of technology transfer than laboratories without them, only 45 percent of the 236 laboratories surveyed were covered by ORTAs at the local or facility level, while 36 percent were covered by an ORTA at the centralized or headquarters level, and 19 percent of laboratories were not covered by any ORTA, often because of personnel limitations or uncertainty about agency policies.
- Over half of the fiscal year 1982 funds available to ORTAs were spent on technical information dissemination, while a lack of resources for adaptive engineering was cited as an obstacle to providing technical assistance to State and local governments.

A broader review of the implementation of Public Law 96-480, conducted by DOC, concludes that the Administration has "made substantial progress in carrying out the *intent* of [the] Stevenson-Wydler Act."[18] It has done so, however, through a "comprehensive strategy" based on "noninterventionist" initiatives, including tax incentives, changes in patent and antitrust procedures, and reallocation of Federal R&D funding.

DOC has not implemented the CITs and accompanying grants called for by sections 6 and 7, citing budget constraints and the greater effectiveness of antitrust legislation (specifically the National Productivity and Innovation Act of 1983, H.R. 3878/S. 1841) in achieving this purpose.[19] Indeed, many cooperative or joint R&D initiatives similar to the CITs have been undertaken by universities and the private sector. DOC concludes that "the Government has a significant opportunity to support the intent of section 6 by providing technical assistance for . . . universities and other nonprofit organizations that request it."[20] NSF's University/Industry Cooperative R&D Experiment, begun in 1973, is counted by both DOC and NSF as creating CITs under section 8 of the 1980 Act.

Pending Legislation

Several other bills now pending and likely to be reintroduced in the 99th Congress also address the Federal role in technology transfer and the development and diffusion of commercial technologies in ways that might increase the Federal contribution to regional HTD. The Manufacturing Sciences and Technology Research and Development Act of 1983 (S. 1286/H.R. 4415), for instance, would permit DOC to establish and support Centers for Manufacturing Research and Technology Utilization similar to the CITs authorized by Public Law 96-480. The Advanced Technology Foundation Act (H.R. 4361) would establish a new Federal agency to initiate and support cooperative applied research through loans and grants, and would also create a Federal Industrial Extension Service.

The National Professions and Technology Foundation Act (H.R. 4245) would also create a new Federal agency, combining some of the functions of DOC and NSF, that would promote not only technology transfer but also development of scientific and technical manpower and of a national information and statistics policy. The National Technical Clearinghouse Fund Act (H.R. 2514/S. 808) would establish a central clearinghouse to enhance technology transfer to private industry and the general public. Another bill (H.R. 2525) would establish a National Commission on Technological Innovation and Industrial Modernization to develop a national industrial policy, including analysis of public policies that hinder industrial competitiveness and strategies for the development and extension of new technologies.

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[18] U.S. Department of Commerce, op. cit., p. 4; emphasis added.
[19] Ibid., p. 14.

[20] Ibid., p. 17.

Regional Development Programs and Tools

While R&D and technology transfer programs have provided an effective stimulus to cooperative HTD initiatives involving universities and private industry, OTA's investigation suggests that the Federal Government has more frequently contributed to HTD initiatives by State and local government through grants and other assistance to community and economic development. In a survey of 54 local HTD initiatives in 22 communities, OTA found that local governments had made use of the following Federal programs:

Urban Development Action Grants	9
Industrial Development Bonds	5
Economic Development Administration grants	4
Community Development Block Grants	3
Comprehensive Education and Training Act programs	2
Free Trade Zone	2
Appalachian Regional Commission programs	2
Small Business Administration loan programs	1

There are currently almost 300 programs providing nearly $100 billion in grants to State and local governments for a wide variety of public services and activities (see table 17). One justification given for this Federal involvement is that States might underinvest in activities whose benefits spill over into other States. Other rationales for Federal assistance are *benefits from centralized coordination,* whether in effectiveness or efficiency, and *equitable distribution of resources* for providing public goods and services, whether for particular recipients or for States and localities generally.[21] Because Federal assistance programs have grown considerably over the past 20 years, the current Administration has proposed a massive realignment of responsibility between the Federal Government and the States.

These Federal programs offer State and local governments flexible tools for regional economic development, including funds, technical assistance and information, planning assistance, and job training or retraining programs. Block grants, training programs, planning grants, and loan funds have been used for a wide variety of projects, often in ways unanticipated or unintended in the original legislation, depending on the needs or desires of different communities. These programs were not designed specifically to promote regional HTD, and in general their influence on regional HTD is indirect and even serendipitous. Nevertheless, they have proven to be an effective adjunct to regional HTD initiatives *when utilized imaginatively, and in conjunction with other HTD efforts, by entrepreneurial local leaders.*

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[21] For an extended discussion of this topic, see Sandra Christensen, Roberta Drews, Patricia Ruggles, and Suzanne Schneider, *The Federal Government in a Federal System: Current Intergovernmental Programs and Options for Change* (Washington, DC: U.S. Congressional Budget Office, August 1983).

Table 17.—Growth in Federal Outlays for Grants, by Function (in millions of current dollars)

	Outlays			Percentage growth in real terms		Percentage change in real terms
Program areas	1960	1970	1980	1960-80	1982 outlays	1980-82[a]
Infrastructure and development						
Energy	$ 6	$ 25	$ 499	2,420	$ 509	−7
National resources and environment	108	42[illegible]	5,362	1,404	4,871	−17
Transportation	2,999	4,538	13,087	32	12,171	−15
Community and regional development	109	1,780	6,486	1,703	5,379	−24
Education, training, and social services	526	6,390	21,862	1,101	16,589	−36
Income security and health:						
Income security	2,635	5,819	18,495	186	21,930	+2
Health	214	3,850	15,758	1,819	18,839	−3
General-purpose fiscal assistance	159	430	8,478	1,441	6,347	−37
Other[a]	264	753	1,445	58	1,559	−9
Total outlays for grants	$7,020	$24,014	$91,472	334	$88,194	−17

[a] Includes grants for national defense, agriculture, commerce, veterans' programs, administration of justice, and general government.

SOURCE: Office of Management and Budget for outlays. Specialized deflators for each spending category were used.

OTA's investigation of the impacts of these Federal programs on regional HTD concentrates on two of the categories listed in table 17:

- *community and regional development,* specifically development grants and business development programs that have contributed to high-technology industrial development initiatives: and
- *education, training, and social services,* specifically science and mathematics education, vocational education, and training programs that have contributed to high-technology manpower initiatives.

The resulting list and the specific examples provided are not comprehensive; in fact, although several directories of such programs exist, there is at present no central, user-oriented source of information for public officials who might wish to undertake similar projects.[22] OTA's intention is instead to provide illustrative examples of the interaction between Federal policies and State and local HTD efforts, in order to reveal areas in which their interaction might be strengthened or improved.

Community Development

Numerous Federal programs, administered by several different agencies, provide financial support for community development or business assistance activities through grants, direct loans, loan guarantees, and technical assistance. In fiscal year 1982, the Government spent about $8 billion for community and regional development and several billions more in loans and loan guarantees to small business. The Federal programs that most frequently contributed to HTD initiatives investigated by OTA include:

- Community Development Block Grants (CDBGs), administered by the Department of Housing and Urban Development (HUD), which provide about $3.5 billion annually to some 1,900 communities in support of housing, infrastructure, and other locally chosen projects;
- Urban Development Action Grants (UDAGs), also administered by HUD, which provide $0.5 billion annually to stimulate commercial and industrial development in distressed communities;
- a variety of grant, loan, and assistance programs administered by the Economic Development Administration (EDA), which promote the long-term recovery and growth of communities adversely affected by economic change; and
- business development programs, including both financial and management assistance, administered by EDA and the Small Business Administration, plus tax-free Industrial Development Bonds (IDBs) that must be approved by the Department of the Treasury.

Community Development Block Grants.—The CDBG Program was created by the Housing and Community Development Act of 1974 (Public Law 93-383) to consolidate a number of categorical assistance programs established by the Housing Act of 1949, 1954, 1955, 1956, 1965, and 1966. As such they represent part of a trend toward consolidation of Federal assistance programs in the 1970's that led to greater flexibility in resource allocation and greater reliance on State and local administrative machinery. CDBG is the largest development assistance program, with funds provided on a formula basis for improvements such as housing rehabilitation, streets and roads, waterworks, and other public facilities. It was originally designed to provide housing and expanded economic opportunities for low- and moderate-income neighborhoods rather than industrial or commercial development.

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[22] See, for example, U.S. Office of Management and Budget, *Catalog of Federal Domestic Assistance,* 17th ed. (Washington, DC: U.S. Government Printing Office, June 1983). The *Catalog,* first published in 1965, contains 963 assistance programs of all types (including economic development) offered by 51 different Federal agencies; it describes briefly the types of projects funded, but provides neither descriptions of innovative program uses nor combinations employed by other communities.

A more focused and usable source for local officials may be *The 1983 Guide to Government Resources for Economic Development* (Washington, DC: Northeast-Midwest Institute, December 1982), which provides descriptions of over 60 Federal assistance programs, cross-indexed by type of need, and detailed examples of the uses, including HTD projects, to which they have been put by State and local governments. The *Guide* also contains descriptions of other Federal resources, including procurement, tax credits, revenue bonds, and the location of Federal facilities, which may also contribute to regional HTD. In addition, it contains a directory of non-Federal resources, such as State economic development programs and private sector involvement, that can be used for local programs.

A directory that focuses specifically on high-technology business assistance is Henry Greenwald (ed.), *Source Guide of Government Technology and Financial Assistance* (Wellesley Hills, MA: Capital Publishing Co., October 1982). This source lists Federal programs for information assistance, technology transfer, R&D support, and general business financing, as well as State government programs for high-technology firms, along with descriptions of users' experiences with them.

A fourth directory, which includes a detailed of State programs only, is the *Directory of Incentives for Business Investment and Development in the United States: A State-by-State Guide* (Washington, DC: Urban Institute Press, 1983), compiled by the Urban Institute in conjunction with the National Association of State Development Agencies and the National Council for Urban Economic Development. This directory contains no reference to Federal programs.

DOC's Office of Productivity, Technology and Innovation is currently compiling a more focused directory of Federal, State, and private assistance programs for small, technologically sophisticated firms. SBA has published similar directories in the past, oriented toward the need of private rather than public users.

Changes made in the program by the Housing and Community Development Act of 1977 (Public Law 95-128) expanded eligibility to include grants to nonprofit neighborhood organizations, local development corporations, and Small Business Investment Companies. Only a portion of CDBG funds—$400 million, or about 10 percent in fiscal year 1981—were used for economic development activities. However, amendments contained in the Omnibus Budget Reconciliation Act of 1981 (Public Law 97-35) further expanded eligibility to include private, for-profit firms engaged in economic development, and gave local jurisdictions greater discretion in how they spend program funds.

As a result of these changes, CDBGs have become a more useful tool for HTD initiatives that emphasize financial as well as physical capital. OTA has identified the following examples of CDBGs used for HTD initiatives:

- Philadelphia Industrial Development Corp.—CDBG money was used to set up a revolving loan fund.
- Phoenix SBA Loan Program.—The city finances its loan program through CDBG funds and by selling debentures.
- Cincinnati, Ohio, Venture Capital Fund.—CDBG funds were used to provide a venture capital pool.

Recent emphasis by the Administration and Congress has been on further consolidating and reducing the CDBG program and decreasing Federal involvement in its operation. The 1981 amendments, for example, transferred responsibility for the Small Cities program from HUD to the States, on the condition that the States consult local officials on how the funds will be used, provide planning and technical assistance, and provide 10 percent matching funds from State resources.

This could serve to increase linkages between State and local government efforts to promote HTD, but concern has been expressed that the needs of urban areas may be ignored in State governments dominated by rural and suburban interests. By reducing the reporting requirements, the amendments may also have reduced both accountability and the availability of valuable information on project design and effectiveness. The most recent amendments, contained in the Housing and Urban-Rural Recovery Act of 1983 (Public Law 98-181), reauthorized CDBG for 3 years at reduced and flat authorization levels.

Urban Development Action Grants.—The 1977 amendments also created the UDAG Program to assist distressed communities that are undertaking economic revitalization programs designed to generate jobs and increase tax revenues. UDAGs are designed to improve the feasibility of otherwise marginal projects by leveraging private sector financial participation, typically at a ratio of about 6 to 1. This requirement can contribute to the success of HTD initiatives like those investigated by OTA by stimulating local networking and partnership and by creating stronger linkages between local, university, and private sector HTD efforts. This has proven most useful in developing physical capital for HTD, such as incubator facilities and technology-based industrial parks.

OTA identified the following applications of UDAG funds to HTD initiatives:

- New Haven Science Park.—UDAG funds were used for site preparation at Science Park, a large tract of land being developed near Yale University for companies engaged in R&D on new products and processes, and related manufacturing.
- San Antonio, TX, Vista Verde South Development Area.—Control Data has constructed a 60,000-square foot building in a 145-acre urban redevelopment area located in San Antonio's inner city and employs 300 people making electronic components. The project was funded by an $18.8 million UDAG and a $4 million CDBG.
- Chicago, Biomedical Research Park.—Both the City and State have worked closely with Applied Molecular Genetics to secure a $2 million UDAG and an $8 million IRB. The University of Illinois, the city, and the State are cooperating in a joint venture to acquire 46 acres of land adjacent to the University's west side

campus and its genetics research center. The site is planned as a high-technology park.

- Lowell, MA.—The city obtained a $5 million UDAG, which was loaned to Wang at 4-percent interest as an incentive to locate in Lowell.
- Philadelphia, University City Science Center.—Federal urban renewal funds were used to prepare the site for this 16-acre urban research center, and a $5 million UDAG has been received for construction of a residential and conference center.
- Philadelphia, Business and Technology Center.—Control Data purchased a 300,000-square-foot building, with the help of a $1.3 million UDAG. The building will be renovated and leased to other companies, and serve as an anchor for HTD in the surrounding 60-acre industrial park.
- Milwaukee, Hilltop Parish Research Park.—This 30-acre site on the city's northwest side was rezoned for research activities only, and the city acquired a $200,000 UDAG for site preparation.

Economic Development Administration (EDA).—EDA was created by the Public Works and Development Act of 1965 (Public Law 89-136) to support the long-range economic development of areas with severe unemployment, low family income, and/or significant population loss. EDA was primarily concerned with rural development until 1969, when it began to offer assistance for urban economic development as well. Amendments passed in 1976 (Public Law 94-487) greatly expanded EDA's mandate by reducing the population requirements for eligibility and adding several new assistance programs. EDA activity reached its peak in 1979, when the agency administered over $1.0 billion in aid, much of it aimed at private firms. By 1983 its budget had been cut by more than half, and the Administration has recommended abolishing EDA.

Although the HUD economic development programs—CDBG and UDAG—have a much larger budget than the EDA programs, all of EDA's programs are focused on economic development, while only small portions of total HUD funds are spent on activities whose specific purpose is to promote economic development. OTA has identified four EDA programs that have encouraged or supported State and local HTD initiatives.

EDA's Public Works and Development Facilities Program provides grants and loans for physical capital improvements, public services, and the acquisition and rehabilitation of property for development. Eligible public works projects include industrial parks and sites, vocational or skill training facilities, recreation projects, and hospitals. As a result, these grants can contribute to local HTD initiatives involving both physical and human capital. Following are examples of EDA Public Works projects promoting HTD:

- $2,075,000 to the city of Boston in March 1978 for development of the Crosstown Industrial Park. The Digital Equipment Corp. has located a plant in the park which employs several hundred local workers.
- $1,125,000 for a skill training center at Lowell, MA, to offer instruction in computers and electronics.
- $820,000 to the Occupational Industrialization Center of Roxbury, MA, for renovation of a building for a high-technology skill center.
- $700,000 to the Occupational Industrialization Center of Port Chester, NY, for another skill center for high-technology instruction.
- $500,000 for the construction of a computer skill training center at Springfield, MA.

EDA's Special Economic and Adjustment Assistance Program supports a wide range of economic activities, with eligibility based on need resulting from "sudden and severe economic dislocation" or "long-term economic deterioration." Adjustment Assistance funds have been used not only for industrial land banking infrastructure and for neighborhood revitalization, but also for economic planning and to establish revolving loan funds. OTA has identified three major revolving loan funds for HTD that were capitalized in part by EDA grants:

- $3 million to the Massachusetts Technology Development Corp.;
- $1 million to the Connecticut Product Development Corp.; and
- $1 million to the New York Science and Technology Foundation.

EDA's Technical Assistance Program (TAP) provided $8.3 million for 154 grants in fiscal year 1982, among which were 36 university business assistance centers that provide feasibility and marketing assistance to existing businesses and help establish new business. In fiscal year 1983 there were 38 centers receiving $3.5 million in grants out of a TAP budget of $8.0 million. A few of these centers are particularly active in technology transfer and local HTD initiatives, notably those at Florida, Iowa, Oregon, and Pennsylvania State Universities; the Universities of Michigan and Southern California; and the Georgia Institute of Technology. A fiscal year 1983 TAP grant also supported the efforts of the National Council for Urban Economic Development to establish a comprehensive information and technical assistance program aimed at helping cities prepare new strategies to meet the needs of high-growth firms. TAP grants have also supported the U.S. Conference of Mayors' Research and Education Foundation, which hopes to strengthen local economic and technology development strategies through better cooperation between cities, universities, and Federal Laboratories.

Business Development

In addition to assistance to State and local governments, the Federal Government also provides support for local economic development through business assistance programs administered by EDA and the Small Business Administration (SBA). These include not only loan and loan guarantee programs, but also equity and bond programs that provide a pool of investment funds for local financial capital initiatives. Tax-free industrial revenue bond (IRB) authority, granted by the Department of the Treasury, also falls in this category; IRBs were in fact the second most frequent form of Federal participation in local HTD initiative investigated by OTA.

EDA Business Development Loan Guarantees.—This program provides loan guarantees for firms in depressed areas, and also guarantees leases held by a business enterprise. The program has recently been reduced in scale and changed from a loan and guarantee program to one providing only guarantees. In fiscal year 1982, 14 loans were approved for guarantee, but in fiscal year 1983 only 2 were approved and none has been approved thus far in fiscal year 1984, with funding at $33 million. Examples of high-technology companies using this program include:

- Univox Corp., a Los Angeles company that makes sea water purification devices, primarily for defense purposes, received a $2 million direct loan in fiscal year 1982, when the direct loan program still existed.
- Systems Management of America Corp. (Norfolk, VA), a defense contractor that makes computer equipment for submarines, received a $5 million loan guarantee in fiscal year 1983.

Small Business Investment Companies (SBICs).—This program, established in 1958, has evolved into a system in which locally organized private investment companies licensed by SBA are eligible to obtain funds from either the Federal Financing Bank or SBA. Such companies must have a minimum capitalization of $500,000, and they receive Federal funds at rates of interest close to or below that which the Government pays for the money. SBICs are obligated to use the funds obtained for equity investments and long-term capital loans to small or disadvantaged businesses.

State governments have not been allowed to put capital in these firms, although some States have either established public corporations that invest in SBICs or given tax breaks to SBICs so that they may assist high-technology small businesses. Some of the more successful SBIC-financed companies include: Advanced Micro Devices; Amdahl; American Microsystems; Computer and Communication Technology; and Teledyne. The Administration has imposed a moratorium on the licensing of new SBICs, although legislation has been introduced to increase the funding available to this program (H.R. 3020, S. 1323). (See ch. 3 for a further discussion of SBICs in local seed and venture capital markets.)

Section 503 Certified Development Companies.—SBA 503 loans are designed to assist small businesses by providing long-term financing (not to exceed 25 years) through the sale of debentures by the Federal Financing Bank. Loans are to assist small businesses in the acquisition of land and buildings, construction, expansion, renovation and modernization, machinery, and equipment. Several local initiatives investigated by OTA have used the SBA 503 loan program to assist fledgling high-technology firms.

Small Business Revitalization (SBR) Program.—HUD and SBA are cosponsors of this economic development program, through which States can leverage private sector investment. Each participating Governor establishes a coordinated small business job creation system, based on private sector financing and local leadership. The system is designed to deliver financial assistance to all parts of the State—especially to small and rural communities that may lack the staff or technical expertise to assemble loan packages. Thirty States have now chosen to provide part of the funds and participate. Phytofarms of America, Inc., a high-technology agribusiness in DeKalb, IL, secured a $2 million loan through the SBR program to save 30 jobs, create 60 new ones, and purchase an existing plant from a Fortune 500 company.

Small Business Development Centers (SBDCs).—Under the SBDC program, States can match their shares of a $65 million Federal authorization to run university-based management assistance centers for small business. Unlike many other SBA programs, SBDCs have a legislative mandate (Public Law 96-302) to assist in technology transfer, make use of Federal laboratory facilities and equipment, and coordinate and conduct research they deem worthwhile. Since the States decide how SBDC money is spent, the program also offers an opportunity to concentrate business development efforts on high-technology firms. Texas has proposed doing this through an SBDC at the University of Texas at Arlington.

It is not known how often SBDCs assist high-technology firms, but evidence suggests they are a minor beneficiary. For instance, one evaluation of the program found that only 10 percent of SBDC clients were in manufacturing, and that only 4 of the 181 SBDC offices established by October 1983 were based in university engineering or technical departments.[23] An informal OTA survey of six large Federal Laboratories found that only one had been contacted by the SBDC, although in that instance the SBDC was apparently an effective liaison between scientists and businessmen.

Industrial Revenue Bonds (IRBs).—The interest from these State and local government bonds is exempted from Federal taxes by the U.S. Treasury. IRBs have been used extensively by municipal governments to attract investment for industrial sites that include high-technology firms, such as Science Park in New Haven, CT. Totaling almost $20 billion in fiscal year 1981, IRBs dwarf all other forms of State and local development resources, and they represent a crucial element in many HTD initiatives.

Education and Training

Education and training are fundamental for developing the human capital needed to exploit innovations and providing a technically skilled work force for regional HTD. About half of the State government HTD initiatives identified in OTA's census involved education and training programs. Many private sector initiatives also involve education improvements, often through loaned personnel or donated equipment. These State and local efforts are supported by Federal policies and programs in three areas: science and mathematics education; vocational education; and training or retraining programs.

Science and Mathematics Education.—Public education is a constitutional responsibility of the States, but its quality affects the Nation's economic productivity. The launch of Sputnik in 1957 prompted concerns similar to those voiced today about the quality of U.S. math and science education. Congress responded at that time with a massive Federal education program, the National Defense Education Act of 1958. After the Sputnik crisis, however, Federal education policy shifted its focus from the quality of education to equality of access. Now, faced with issues such as the level of innovation, economic productivity, international competitiveness, and the impact of new technologies on the work force, attention has again been directed toward math and science education. A number of commission reports have raised concern about the quality of U.S. education, specifically such problems as a shortage of qualified math and science teachers, insufficient high school math and science course requirements, and a lack of priority for excellence in education.

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[23] Centaur Associates, Inc., *An Evaluation of the Economic Impact of the Small Business Development Center Program* (Washington, DC: SBA contract No. 6027-MA-82), p. v.

Legislation now pending and likely to be reintroduced in the 99th Congress includes proposals for initiatives such as tax incentives for companies donating computers and technical equipment to schools; loans and incentives for individuals to become science and math teachers; programs for joint teacher/industry employment; and funding for staff development programs. Two bills have emerged as the major packages of education legislation in the 98th Congress: the Emergency Mathematics and Science Education Act (H.R. 1310) passed the House on March 2, 1983; the similar Education for Economic Security Act (S. 1285) was reported to the Senate in June 1983 but no further action has been taken. Both bills authorize $425 million for a variety of new programs designed to improve teaching and increase the number of both engineering personnel and science and math teachers at all educational levels. The two bills, however, have structural differences. While both require the sharing of administrative responsibilities by the Department of Education and National Science Foundation, different programs and roles are assigned to each organization. Also, a second major difference is the manner in which the formula grants are distributed to State and local entities, with population the major factor in the Senate bill, while poverty level and school-age population are given equal weight in the House bill.

Vocational Education Programs.—The Department of Education, which administers the Vocational Education Program (VocEd), has no dedicated high-technology training programs. VocEd has been criticized in the past both for training for obsolete skills and for using outmoded equipment. However, a number of local VocEd programs have been directed toward skills needed for high-technology industries, such as:

- Triton College, Rivergrove, IL (CAD/CAM training);
- Piedmont College, Greenwood, SC (robotics);
- Tri-County Technical College, Pendelton, SC (microelectronics);
- Rivard Community College, Rivard County, FL (robotics); and
- Lively Area Vocational Technical Center, Tallahassee, FL (laser optics and electronics).

VocEd is awaiting reauthorization this year, and several of the reauthorization bills specifically address high-technology training. The House has passed the Vocational Technical Education Act of 1983 (H.R. 4164), which extends vocational education for 5 years and attempts to correct these problems by authorizing appropriations for activities such as industry/education partnerships for training in high-technology occupations; adult training, retraining, and employment development; and entrepreneurship programs. Other reauthorization bills would consolidate vocational and adult education programs through block grants to the States (S. 1039/H.R. 2940), amend the program to emphasize high-technology training (H.R. 4793, S. 1094), or provide additional incentives for equipment donations (H.R. 3280 and H.R. 4244). Funding levels were $729 million in fiscal year 1983 and $738 million in fiscal year 1984.

Training.—Federal training programs are generally justified on the grounds of providing equity to poor and disadvantaged individuals; easing and quickening the transition of displaced workers; and training the work force to use new technologies efficiently. Major policy questions surrounding training are the criteria that should be used to determine eligibility for training programs (e.g., poor, disadvantaged, handicapped, displaced, or minority) and the appropriate level of involvement for the public and private sectors. Currently, Federal training programs account for only 7 percent of total training expenditures in the United States; State and local programs account for most of the government-sponsored training.

Private industry currently spends about $30 billion on job training and retraining, according to the American Society for Training and Development, an amount equal to three times the level spent by Federal, State, and local governments combined. The 200 or 300 largest companies account for the majority of training programs. Still, many believe that U.S. industry underinvests in human capital and should spend more on worker training. Hence, a number of proposals now before Congress call for additional incentives to private industry to increase their investments in human capital.

The first Federal civilian job training initiative since the New Deal was the Area Redevelopment Act of 1961 (ARA). As part of its provisions to help economically depressed localities attract new industries, ARA authorized a limited amount of training to ensure the availability of a skilled work force for newly created jobs. Persistently high unemployment rates led to the enactment, in 1962, of the Manpower Development and Training Act (MDTA), which authorized a broader array of training services and allowances and replaced the training programs of the ARA. In 1964 Congress passed the Johnson Administration's Economic Opportunity Act, which instituted a wide range of programs designed to eradicate poverty, including training programs targeted for the poor, minorities, and youth. Training and retraining are also available to displaced workers under EDA's Trade Adjustment Assistance, a result of legislation dating to 1962, but this training provision has seldom been used.[24]

The proliferation of training programs during the late 1960's led to the enactment in 1973 of the Comprehensive Employment and Training Act (CETA), which consolidated many of the existing work and training programs. CETA was amended in 1974, when a public service jobs program was added, and again in 1976 when the public sector employment program was expanded. The last rewrite of CETA, in 1978, targeted training toward low-income and disadvantaged individuals, but added a Private Sector Initiative Program to involve industry in training activities. CETA was frequently criticized for creating too many public sector jobs and having too little private industry involvement. Examples of CETA projects that were part of local HTD initiatives include:

- Colorado Springs, CO, Institute for Business and Industrial Technology.—IBIT is a skill center that has been in operation for nearly 2 years. It trains students to fill entry-level technical positions and offers an associates degree in electronics. The Institute was funded by CETA until October 1983, when the Job Partnership Training Act took over.
- Montgomery County, MD, Upgrading Skills Training Program.—This program is run by the County Department of Economic Development with CETA/JPTA funds. It involves all types of firms, including high-technology. It identifies firms that need to upgrade their employees' skills and then works with the company to design a curriculum and select employees for the program.

The Job Training Partnership Act of 1982 (JTPA, Public Law 97-300) replaced CETA in October 1983. Like CETA, JTPA is meant to train and employ the chronically jobless, especially disadvantaged youths and the structurally unemployed. The main differences between the two are that private industry councils (PICs), rather than local government, will decide what training will be provided (based on what jobs are available); and that no public sector jobs will be created. Like recent changes in general development programs, described above, JTPA thus represents a consolidation and reduction in Federal assistance to State and local governments, combined with increased State and local responsibility for program administration. However, by also increasing private sector participation through local PICs, JTPA may also contribute to local networking and institutional cooperation, which OTA has found to contribute to successful HTD initiatives.[25]

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[24] Steve Charnovitz, "Trade Adjustment Assistance: What Went Wrong?" *Journal of the Institute of Socioeconomic Studies*, vol. 9, No. 1, spring 1984, pp. 26-39.

[25] Further discussion of education- and training-related issues in high-technology industry can be found in the following OTA publications: *Informational Technology and Its Impact on American Education* (OTA-CIT-187, November 1982); *Automation and the Workplace: Selected Labor, Education, and Training Issues—A Technical Memorandum* (OTA-TM-CIT-25, March 1983); *Computerized Manufacturing Technology: Employment, Education, and the Workplace* (OTA-CIT-235, April 1984); and *Technology and Structural Unemployment: Retraining Adult Displaced Workers* (ongoing).

Planning, Demonstration, and Models

In addition to the more general programs described above, a small number of Federal programs have contributed more directly to regional HTD initiatives by encouraging State and local groups to establish new institutional linkages or administrative mechanisms. These programs have been very small in comparison with CDBG or CETA, and only a few were longstanding. Nevertheless, they have allowed local groups to experiment with different approaches to regional HTD, and in some cases they have developed or demonstrated models for State and local HTD initiatives that have been successfully replicated elsewhere.

It is difficult to determine precisely how effective these programs have been in promoting HTD, since they have yet to be evaluated in a rigorous or comparative fashion. However, the fact that they have been considered or adopted by other States and localities suggests that the Federal Government has played a useful role in encouraging these experiments. The principal examples of this role identified in OTA's investigation were the State Technical Services Program (STS) and several cooperative programs supported by NSF.

State Technical Services Program

STS was one of the few Federal programs specifically designed to assist States governments in improving their capabilities for dealing with problems involving science and technology. STS was designed to accelerate the utilization of new technologies through locally planned programs to put them directly in the hands of business and industry. Established by the State Technical Service Act of 1965 (Public Law 89-182), STS had given grants to all 50 States, totaling $10.9 million, by fiscal year 1969. There were few restrictions on use, and in fact one criticism of STS was that it provided little guidance to States on how to assist high-technology industry. Some States, like Pennsylvania and North Carolina, started industrial extension services modeled after agricultural extension; others, like New York, formed science and technology organizations modeled after NSF. Many States, however, failed to establish permanent programs.

An evaluation of STS by A. D. Little, Inc., found that benefits to firms from the three or four most successful cases in each State were at least three times the total Federal expenditure for the extension service in a year.[26] The eventual benefits and return in taxes were estimated to be well above the cost of the program. The evaluation recommended that Federal support be continued and even increased, and that greater attention be given to increasing communication between States in order to facilitate exploitation of useful results and techniques. Nevertheless, few of the efforts begun under STS were successful enough to receive further State funding after the end of Federal support. The exceptions were notable, however—several of the programs identified by OTA's census of State government HTD initiatives were founded under STS, and several others were based on these successful models.

- The Pennsylvania Technical Assistance Program (PENNTAP) is one existing vestige of STS. PENNTAP offers assistance to industry through field offices at 24 campuses of Pennsylvania State University. PENNTAP generally reacts to requests rather than initiating technology transfer, a mode that both PENNTAP administrators and NSF observers say works best, in part because extension officials may not know the needs and constraints of potential clients. PENNTAP was in turn the precursor of Pennsylvania's ambitious Ben Franklin Partnership initiative.

National Science Foundation

OTA also identified three NSF programs designed to develop and demonstrate HTD mechanisms. Two were directed to university settings, while the other (like STS) was aimed at State and local governments. All three have been successfully replicated.

Innovation Centers Experiment.—NSF's Innovation Centers Experiment was initiated in 1973 to increase university coursework and clinical experience in the commercialization of new ideas, and thus heighten the entrepreneurialism of participating students. The program also experimented with indirect aid to high-technology entrepreneurs through three different types of university-based assistance programs: product testing and evaluation services; technical extension; and incubation facilities. A total of 10 Centers were funded by the end of the program in fiscal year 1981. Total NSF grants amounted to about $5.2 million; a small amount of fiscal year 1981 funds is still available, since the Innovation Centers received funding for 5 years to ensure stability. NSF has only recently begun a final evaluation of the experiment, which was terminated in

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[26] Arthur D. Little, Inc., *Program Evaluation of the Office of State Technical Services*, prepared for DOC's Office of Program Planning, contract No. 9-35335, October 1969, pp. 17, 24, and 29.

1981 in favor of the University/Industry Cooperative R&D Experiment.

Of the three original Centers, one concentrated on student entrepreneurship (MIT), one provided an incubation facility for small local firms (Carnegie-Mellon), and one sold consulting services to private innovators (University of Oregon). Six of the later Innovation Centers concentrated on new product and new business development, rather than product evaluation or student entrepreneurialism; the seventh was an extension service (University of Arkansas). Later facilities concentrated more on assisting local entrepreneurs by providing technical assistance and incubator facilities, space on campuses for business offices, and laboratories near students and faculty. As such, they represent models of several types of HTD initiatives described in chapter 4: R&D and technology transfer; entrepreneurship training and assistance; and physical capital.

An interim NSF evaluation hailed the experiment a success.[27] In the first 4 years the Innovation Centers participated in the creation of over 30 new ventures, of which 23 have reached the market. Sales total of these firms exceeded $30 million, approximately 1,000 jobs were created, and more than $6 million in tax revenues were generated. More than 2,000 students gained instruction or experience in the entrepreneurship, invention, or innovation processes. The study found the major factors determining program success included the caliber of directors, the quality of work, the attitudes of established university departments, stability and flexibility through 5-year block funding, and NSF's yielding of patent rights to participant firms.

The incubator facilities at Universities of Utah and New Mexico are widely considered to be the most successful centers; MIT's center has also been called a success, although it no longer concentrates on student entrepreneurship. Only one innovation center has become financially successful, and several factors have contributed to the problems experienced by other centers: the Federal Government's expenditure gained it no rights to innovations at the centers, and the Federal subsidy was often competing or generating competitors with existing private sector business consulting firms. University acquisition of equity through the Innovation Centers might also create an additional problem: conflict of university interests if it both educates entrepreneurs and takes an interest in their businesses.

Facilities similar to the NSF Innovation Centers have been established by other State governments, universities, and private sector groups in recent years. None have been modeled directly on these 10 centers, although numerous delegations have visited and studied them to learn whatever lessons might be applied to their own regions and situations. Innovation centers elsewhere that have consulted NSF include:

- Georgia Tech's Advanced Technology Development Center, which has an incubator facility akin to the Carnegie-Mellon Innovation Center model.
- University of Wisconsin at White Water, which has established an invention evaluation facility that learned from the unsuccessful University of Oregon Innovation Center.
- University of Michigan at Ann Arbor, Institute for Research and Technology, Industrial Development Division, which operates a management and technical assistance center akin to the extension service NSF supported at the University of Arkansas.
- University of Missouri at Rolla, which is developing a multiple service center including incubator, product evaluation, and technical and management services, which combines elements of several NSF centers.

University/Industry Cooperative Research Centers.—This experiment, which was begun at the same time as the Innovation Centers in 1973, was designed to promote innovation through R&D and technology transfer rather than entrepreneurship assistance. Cooperative R&D attempted to move technology to the marketplace by matching university research capabilities with the needs of industry, which shares the cost of the research with the Federal Government. NSF initially funded three centers from among 14 university and corporate applicants who received planning grants in 1973. Criteria for selection were the institutions' ability to plan the cooperative effort, obtain industry commitments (like UDAGs, the grants require proof of private participation), and agree on allocation of patent rights. NSF guaranteed 4 years of funding and Federal declination of patent rights resulting from the research conducted at the centers.

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[27] *Analyses of Five National Science Foundation Experiments To Stimulate Increased Technological Innovation in the Private Sector*, NSF 82-32, 1982.

MIT, North Carolina State University (NCSU), and the Mitre Corp. received awards. MIT performed cooperative polymer processing research, while NCSU operated an extension service to assist the furniture industry, and Mitre acted as a broker to bring together university and industry expertise for energy research. Since 1973, Mitre's center has closed, NCSU's has switched its focus from furniture to signal processing, and 10 additional centers have been funded, all of them located at universities. In the first 5 years, NSF spent $2.4 million on three centers, which was matched by about $3.0 million from 24 private firms. By the end of fiscal year 1982 there were 13 centers, to which NSF had obligated approximately $5.7 million, matched by approximately $16 million in research funding from industry.

State Science, Engineering, and Technology Program (SSETP).—NSF's Intergovernmental Science and Technology Program (ISTP) was established in 1967, but through fiscal year 1972 it had spent only $2.6 million on a number of small State and local projects. President Nixon's Experimental Research and Development Incentives Program increased ISTP's funding significantly in the early 1970's.[28] One program, Technical Assistance Grants to State executive branches and legislatures, supported staff or consultants to provide technical assistance in State policy or research offices. It was enhanced through the addition of SSETP in fiscal year 1977.[29]

SSETP's goal was to improve the policy management process through studies of the present and planned use of scientific and technical resources in 49 State executive branches and in 42 legislatures. Eight executive branches and seven legislatures were given follow-on awards to implement the recommended changes in their mechanisms for providing technical expertise. Seventeen similar awards were planned but not made in fiscal year 1981 because of budget cutbacks. In many cases, however, State governments implemented the recommended changes without Federal funds, and many of the State initiatives identified by OTA trace their origins to this and other NSF programs. The total budget for SSETP was $5.1 million for fiscal year 1977-81.[30] Overall, ISTP had awarded $41 million by fiscal year 1983, including $7.2 million to State executive branches, $3.9 million to State legislative branches, and $20.6 million to local governments.

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[28] President's Message to Congress on Science and Technology, Mar. 16, 1972.

[29] Legislative mandate for this program is found in the committee report on H.R. 12566, the NSF authorization for fiscal year 1977.

[30] Survey of nine State science and technology foundations. Study funded by NSF. "While these science foundations did not spark the degree of economic development desired or expected, the successful ones attracted at least four new development dollars for each foundation dollar. The additional taxes generated from these new development dollars have at least equaled the foundation's appropriations."

Appendixes

APPENDIX A

High-Technology Location and Regional Development: The Theoretical Base*

Summary

Two major bodies of economic theory shed light on the potential impacts of high-technology industrial development initiatives. Theories of regional economic development provide a better understanding of the role of high-technology complexes in the growth of regional economies, but they do so on a macroeconomic level and explain only partially or implicitly the factors that influence the creation of those centers. Industrial location theories, on the other hand, identify the determinants of business site selection and location decisionmaking on a microeconomic level. To the extent that they address the decisions of high-technology firms, therefore, they can provide an understanding of what conditions or attributes of particular communities will make them most attractive for high-technology development.

Regional economic development theories deal with technological change and the role of high-technology industry in a variety of ways. *Export base theory* suggests that the more successful interregional and intraregional export industries are technology-intensive, and that high-technology industries thus have higher multiplier effects that hasten the process of regional economic growth. *Factor price equalization theories* explain that capital and labor flow between regions seeking their highest return; this may have been a factor in high-technology Sunbelt growth over the past 20 years, but per-capita income convergence in the United States may soon reverse this trend. *Growth pole theory* recognizes the importance of propulsive, high-technology sectors in the urban growth process, and explains how such centers can perform as incubators or seedbeds for the birth of new companies. *Product lifecycle theories* recognize that products, firms, and industries have different locational requirements at various stages of their technological development: while new product development tends to take place in R&D-intensive locations like Boston or San Francisco, mass production techniques allow production to take place in more peripheral low-cost areas like the Sunbelt or the East. *Diffusion theory* demonstrates that the speed with which productivity-enhancing innovations spread between regions can play a critical role in accelerating the economic growth process. When growth pole and product lifecycle theories are integrated into a *regional lifecycle theory*, they provide a particularly appropriate explanatory framework for understanding the development and impacts of high-technology complexes: growth centers in the Sunbelt are seen to be new economic structures that have bypassed the obsolescent technologies of the old industrial heartland, but increasing inflation in these growth areas may result in a new regional equilibrium and the reemergence of the indigenous technological potential of the older heartland.

Industrial location theory indicates that the executives of high-technology companies make their locational decisions in much the same way as executives of other companies, but that the factors that attract them to a community (or at least the priority given to various factors) can be different from other types of industry. *Appropriate labor*, for example, is by far the most important single factor in high-technology location decisions, but with the skill level of the labor force replacing general availability and wage scales as the determining criterion. On the other hand, high-technology firms put less weight on relative costs of *transportation*, since they are less closely tied to the location of materials or markets than other industries.

Because of the increasing competition for high-technology jobs, it has become even more important recently for communities to be aware of the location factors that are important to corporate executives. Community development officials need to assess their locational attributes in a realistic manner, matching their characteristics with the factors that are considered important by particular industries and concentrating their development strategies on rectifying their deficiencies or building on their strengths, as appropriate. This does not mean that a community has to simply look at a laundry list of important factors and fill in the blanks in order to attract high-technology development. In most cases, however, based on the needs of high-technology firms and industries, communities would probably wish to investigate potential linkages with their existing base and to foster one or more of the following: manpower training or retraining, technical and financial assistance, and improved access to cultural and recreational amenities.

Introduction

Many State and local governments, as well as universities and business groups, have established programs to stimulate the creation, attraction, and retention of high-technology businesses. In general, these initiatives are intended to increase the level of technological innovation in a specific region or community, or to make the area more attractive to high-technology industries in order to influence the location decisions of individual firms and entrepreneurs. To be effective, such programs should be based on an understanding of the factors that determine the geographical distribution of high-technology industrial development, its potential role in regional economic development, and the attributes that influence the business location decisions of high-technology firms and entrepreneurs.

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*The material in this appendix is based on the contractor report, "A Review of Regional Growth and Industrial Location Theory: Towards Understanding the Development of High-Technology Complexes in the United States," prepared for OTA by John Rees (Syracuse University) and Howard Stafford (University of Cincinnati), May 1983.

Two major bodies of economic theory shed light on how and why high-technology industrial complexes develop around the country: 1) theories of regional economic growth, and 2) industrial location theory. This appendix begins with a review of several partial theories of regional economic growth, each of which deals at least implicitly with the role and impacts of technological change in regional economies. Because these theories deal with regional development at a macroeconomic level, their usefulness in understanding the patterns of high technology depends on the cumulative effect of location decision by individual firms. Theories of industrial location, in turn, shed light on what conditions or attributes of particular communities are most likely to influence the location decisions of high-technology companies.

Regional Growth Theories and the Development of High-Technology Complexes

Introduction

Most economic theories that purport to explain regional economic growth address the role of technological change, at least implicitly, and there is growing evidence that the factors influencing technological change may vary between regions in a systematic manner.[1] A review of these theories to determine how they deal with technological change and its role in the development of high-technology complexes suggests that there is no single, acceptable, comprehensive regional growth theory, but rather a set of partial theories that explain different aspects of the regional development process.[2] There have been attempts to synthesize these partial theories into a single regional growth theory.[3] They nevertheless remain difficult to operationalize for policy guidance in designing high-technology industrial development initiatives. These partial theories involve:

- the role of a region's export base,
- regional income convergence or divergence over time,
- growth pole theory,
- regional diffusion processes, and
- product and regional lifecycles.

Export Base Theory

Several researchers have stressed the role of exports as the initial trigger for regional growth.[4] At its simplest, export base theory states that a region's growth rate is a function of interregional and international export performance:

> This ability to export induces a flow of income into the region which, through the familiar multiplier effect, tends to expand the internal markets of the region for both national and region-serving goods and services. . . . As the regional market expands and region-serving activities proliferate, conditions may develop for self reinforcing and self sustaining regional growth, and new internal factors may become important in determining the rates of regional growth, such as external economies associated with social overhead capital and the agglomeration of industries, and internal economies of scale.[5]

The resource endowments of a region can therefore determine its competitive advantage over other regions, and such endowments can be modified through technological change as well as changes in the labor force or capital pool. For example, Texas Instruments was originally founded by three individuals who had relocated from the Northeast in the 1930's in search of oil, and, due to the lack of indigenous technology, began building their own instruments and equipment.

Export-producing industries result in a regional balance-of-payments surplus, and they also tend to have strong forward and backward linkages with other industries in other regions. This in turn helps to integrate the developing region into the national economy. Furthermore, "export industries tend to be technologically advanced and to operate at higher levels of productivity . . . [generating income that] filters through the region and helps to spur development of residentiary [nonexport] industries."[6] Hence, export base theory recognizes the higher multiplier potential of high-technology sectors, although the exact nature of such multipliers has not been determined through empirical research.

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[1] John Rees, "Regional Industrial Shifts in the U.S. and the Internal Generation of Manufacturing in Growth Centers of the Southwest," in *Interregional Movements and Regional Growth*, W. Wheaton (ed.) (Washington, DC: Urban Institute, 1979). Others noting this factor include Thomas and Le Heron (1975), Oakey, Thwaites, and Nash (1980), Joint Economic Committee (1982).

[2] P. Lloyd and P. Dicken, *Location in Space: A Theoretical Approach to Economic Geography* (New York: Harper & Row, 1977). Also, Weinstein and Firestine (1978).

[3] H. Richardson, *Regional Growth Theory* (London: MacMillan, 1973).

[4] H. Perloff and L. Wingo, "Natural Resource Endowment and Regional Economic Growth," in *Natural Resources and Economic Growth*, J. Spengler (ed.) (Washington, DC: Resources for the Future, 1961). Also, North (1955).

[5] Perloff and Wingo, op. cit., p. 200.

[6] B. L. Weinstein and R. Firestine, *Regional Growth and Decline in the United States* (New York: Praeger Publishers, 1978), p. 62.

Regional Income Inequality Theories

Two types of theories explain regional growth in terms of income inequality, usually focusing on developing countries or growth regions in more advanced economies. These theories suggest that the regional development process, once triggered by some initial stimulus, tends to be cumulative in nature.

Factor Price Equalization Theories.—The notion of convergence in regional incomes emerged from theories of international and interregional trade. These models assume that factors of production—capital and labor in particular—are "free" to move between regions to seek their point of highest return. The flow of investment capital from Northern to Southern States in the 1970's, for instance, can be seen as movement from areas of low return to areas of high return.[7]

Interregional flows eventually reach an equilibrium where per-capita income is equalized between regions, and evidence shows that a significant regional income convergence took place in the United States over the last 50 years.[8] In 1929, per-capita income in the Southwest was only 53 percent of the U.S. average, but by 1976 this had reached 84 percent of the U.S. average. During the same time period all but two of the industrial States of the Northeast and Midwest showed relative declines in per-capita income, with drastic declines in New York, Connecticut, and Delaware. Since the Sunbelt States were the largest recipients of both physical and human capital over this period, the attempts of both industrial companies and individuals to maximize income do seem to be causing income convergence between regions.

Patterns of capital mobility within regions, however, are more complex. "Income analysis of economic and population trends during the seventies indicates that a powerful decentralization of activity was occurring . . . [but] important qualifications need to be made about the periphery, for it was not an economic monolith."[9] Unequal growth rates among the Sunbelt States may reflect large differences in their industrial structure:

> The dominant industries in the Carolinas, Tennessee, and Texas have included textiles, apparel and food processing—all comparatively labor intensive and low-wage industries at the mature end of their technology cycles. Nearly 42 percent of the South's manufacturing employment are in low-wage industries as compared to only 20 percent for the U.S. as a whole. The South employs only about 25 percent of its manufacturing workers in high-wage industries as compared to 37 percent for the United States.[10]

The regional income convergence between North and South, in other words, appears to have been led by the decentralization of relatively low-technology industries, or by low-technology sectors of high-technology industries. This trend can also be explained as a regional manifestation of the product lifecycle model, discussed below.

Unbalanced Growth Theories.—While factor equalization theories see regional convergence as the mechanism by which growth is transmitted throughout the national economic system, advocates of unbalanced growth strongly dispute the effectiveness of these spread effects.[11] One theory of unbalanced growth centers on the notion of "cumulative causation," wherein market forces tend to attract economic activity to areas that acquired an initial advantage through location, technology, or some other factor. Peripheral regions will experience some growth through spread effects, but lagging areas are debilitated by "backwash effects": labor and capital migrate to the growth center, while low investment in public services inhibit the development of peripheral areas. Only when spread effects are stronger than the backwash will new economic centers emerge as the foundation for future regional growth.

Growth Pole Theory

The notion that regional growth initially occurs around one or more regional centers of economic strength can be traced to the French economist Francois Perroux, whose original conception of growth poles referred to industrial sectors rather than their spatial manifestation. Growth poles were transformed into a spatial concept by regional planners under the term "growth center."[12] Polarization—growth of such poles—depends on propulsive institutions such as fast-growing industries, innovative companies and research universities. Such institutions drive the growth of their economic sector, but "there [also] appear to be significant spatial polarizing influences present in the working of the multiplier."[13] These geographical forces include the operation of scale factors (specifically agglomeration economies), the spatial clustering of innovations and the nature of industrial decisionmaking (discussed below).

Growth pole theory therefore recognizes the link between technology, innovation, and regional economic growth more explicitly than the other theories reviewed so far:

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[7] W. Wheaton (ed.), *Interregional Movements and Regional Growth* (Washington, DC: Urban Institute, 1979).

[8] Weinstein and Firestine, op cit.

[9] W. Keinath, "The Decentralization of American Economic Life: An Income Evaluation," *Economic Geography*, vol. 58, 1982, p. 356.

[10] Weinstein and Firestine, op. cit., p. 51.

[11] G. Myrdal, *Rich Lands and Poor* (New York: Harper & Row, 1957). Also, Hirschman (1958).

[12] D. F. Darwent, "Growth Poles and Growth Centers in Regional Planning: A Review," *Environment and Planning*, vol. 1, 1969. Also, Hansen (1972).

[13] Lloyd and Dicken, op. cit., p. 406.

> Thus one may envisage the situation of a growing, successful economic system, say an industrial city, drawing to it the ideas of spatially dispersed inventors searching for sponsorship, pulling in the skills of migrants, investing its own funds in the search for invention, and using its accumulating capital and labor to convert this flood of new technology into effective use.[14]

This centripetal movement accelerates local growth by enhancing the potential for invention and innovation.[15] The major advantages of large urban areas, in fact, may not lie in their economic base, in the traditional sense, but rather in their capacity to innovate, as reflected in universities and research institutions with an explicit concern for creativity.[16] This would help to explain the role of the Massachusetts Institute of Technology and Stanford University in the creation of Route 128 and Silicon Valley, respectively. And since most new businesses tend to stay in areas where their founders were initially located, it is also likely that large urban areas will spawn more new companies than small communites: their agglomerations serve as seedbeds or incubators for the creation of new firms.[17]

There is little empirical evidence on how urban growth poles act as industrial seedbeds, but there is evidence that firm creation and innovation diffusion may be highly related to personnel movements between firms in the same and related sectors. Research on the spinoff process in the San Francisco area reveals that small firms have higher spinoff rates than large firms, but this may not hold true over time or over space.[18] One key variable that has received little attention is the role of organizational structure and corporate policy in the spinoff process. In this respect, one can classify spinoff firms according to how they came about:

- *Competitive spinoffs*, where employees leave a parent company and establish their own companies, whose products compete directly with those of the initial parent. Because many buyers require a "second source," the need for duplication and standardization of products can be a major stimulus for spinoff here.
- *Backward linked spinoffs*, where employees set up their own company to supply the parent with needed materials or services. This may result from a conscious policy decision by the parent company to buy rather than make a product it needs, i.e., where the spinoff is directly encouraged by the parent.
- *Forward linked spinoffs*, where employees set up a company to market products on which they worked for the parent. This may occur where an employee identifies a potential use for a product and decides to market the idea himself. This could have a major effect on the diffusion and adoption of a particular product.

Corporate policy can also influence regional rates of firm creation, since large firms can limit the number of external spinoffs by encouraging internal spinoffs for risky R&D ventures. Texas Instruments, for example, finds and keeps technical entrepreneurs through a small business development scheme within the company; this may be one reason why the number of spinoffs in the Dallas area (where Texas Instruments is the leading electronics company) is low in comparison with the number of spinoffs from Fairchild in the San Francisco Bay area. One would expect the larger urban growth poles to be the most fertile spawning grounds for new high-technology companies, but the faster growth of small and medium-sized growth centers in recent years suggests that agglomerating tendencies are also at work in these smaller communites. High-technology complexes can apparently develop in a wide variety of locations, and the next round of high-technology development may well be away from large growth poles (e.g., Boston, San Francisco, New York, Dallas, and Phoenix) and towards medium-sized growth centers—places like Austin, Albuquerque, Colorado Springs, and Portland, which are small enough to offer a superior quality of life but still large enough to provide necessary services and economic bases.

Diffusion Theory

Studies of technology transfer and the diffusion of industrial innovations often ignore the regional context of innovations.[19] Conversely, geographers who study the innovation diffusion process usually focus on consumer rather than industrial innovations.[20] There thus exists a need to integrate appropriate elements of both economic and spatial models of innovation diffusion. Four different approaches have been proposed:[21]

- *the adoption approach*, which focuses on the process by which adoption occurs, mostly as a function of the learning or communications process;
- *the market and infrastructure approach*, focusing on the ways in which adoption conditions are made available via diffusion agencies and adoption strategies;

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[14] Ibid., p. 409.

[15] A. Pred, "Diffusion, Organizational Spatial Structure and City-System Development," *Economic Geography*, vol. 51, 1975.

[16] Wilbur Thompson, "Internal and External Factors in the Development of Urban Economies," in *Issues in Urban Economies*, H. Perloff and L. Wingo (eds.) (Baltimore: Johns Hopkins Press, 1968).

[17] R. Struyk and F. James, *Intrametropolitan Industrial Location* (Lexington, MA: Lexington Books, 1975). Also in Cooper (1971) and Danilov (1972).

[18] A. C. Cooper, "Spin-Offs and Technical Entrepreneurship," *IEEE Transactions on Engineering Management*, EM-18, 1971.

[19] E. Mansfield, et al., *The Production and Application of New Industrial Technology* (New York: W. W. Norton, 1977). Also, Gold (1977).

[20] T. Hagerstrand, *Innovation Diffusion as a Spatial Process* (Chicago: University of Chicago Press, 1967). Also in Brown (1980).

[21] L. Brown, *Innovation Diffusion* (London: Methuen, 1980).

- *the economic history perspective,* which emphasizes the dynamic, evolving nature of innovations; and
- *the development perspective,* which focuses on the impact of diffusion on employment and regional disparities.

Based on these four approaches, four models of innovation diffusion models can be identified:

- The *epidemic diffusion model,* which emphasizes distance-decay factors and the logistics curve, where diffusion is seen as a function of the contact system of adopters. The "friction of distance" implies that the diffusion or spread of innovations is most effective in areas close to the point of origin (see below for more detail).
- The *hierarchical diffusion model,* in which innovations filter down the urban size hierarchy; this does not necessarily imply a rigid progression from larger to smaller urban centers for all types of innovations, since the organizational structure of multilocational companies can cause diffusion to flow from small city to large or from large city to even larger, or between cities of approximately the same size.[22]
- The *interindustry diffusion model,* emphasizes the sectoral environment of a firm and the importance of variables such as market structure, profitability, access to capital markets, and age of capital stock in explaining the diffusion process.[23]
- The *interorganizational diffusion model* focuses on the internal characteristics of firms as determinants of diffusion, together with attitudinal and information variables.

These models have not yet been integrated into a comprehensive diffusion theory because they operate at different levels of analysis:

> The epidemic and hierarchical diffusion models, strictly viewed, deal with the question of how a phenomenon develops in time and space, while only the industry-specific and firm-specific models attempt to answer the question of why a particular diffusion pattern emerges. . . . If one thus questions the influence of space on the diffusion of innovations one must proceed from both of the last-named models and investigate how the validity of these models is modified by the fact that the economic subjects are exposed to varying locational environments.[24]

Product and Regional Lifecycle Theories

Building on growth pole theory, and recognizing the propulsive nature of technology in changing regional economic structure, regional researchers in the 1970's turned to the product and technology lifecycle models for more appropriate explanations of the changing locational requirements of firms whose products are at different stages of maturity.[25]

Briefly, the product cycle model is based on the premise that products evolve through three distinct stages:

- *an innovation stage,* where a new product is developed and manufactured in the home region and introduced in a new market area by exports;
- *a growth stage,* in which external demand (interregional or international) expands to a point where direct investment in production facilities becomes feasible and when process technology can be transferred; and
- *a standardization stage,* when production may shift to low-cost locations.

This model has an explicit locational dimension, since each stage of the product cycle has different locational requirements. The innovation stage, which needs a high input of R&D, is usually carried out in high-cost areas, as in the case of mini- and microcomputers in California and Massachusetts. The standardization phase, on the other hand, favors low-cost locations, typically peripheral areas where labor costs and the level of unionization are low. This part of the theory explains the early loss of nearly 1 million production jobs from the Manufacturing Belt to the Sunbelt and foreign locations between 1947 and 1963.

As production operations accumulate in peripheral growth centers, however, external economies will increase in those locations, particularly agglomeration effects, and service infrastructure. When demand in the receiving region grows to a critical threshold, industrial growth takes off on its own through an indigenous seedbed effect—large branch plants begin spawning small new companies, particularly in high-technology sectors.

Aiding this growth process in the new region is the immigration of entrepreneurs. Evidence of such developments can be seen in the once-peripheral growth centers or "sunspots" of the South and West, such as the Dallas-Forth Worth area.[26] This spatial manifestation of the product cycle implies that, over time, regions can change their roles from recipients of innovation via branch plants to generators of innovation through indigenous growth.

The Manufacturing Belt has traditionally served as the seedbed of innovation for the American industrial system, but the diffusion of technology-intensive growth sectors to peripheral growth centers suggests that the innovation potential of the Manufacturing Belt has been eroded and that of the periphery enhanced. Shift-share analysis shows that the Manufacturing Belt specializes in nationally declining industries, whereas the industrial mix of peripheral areas showed a greater share of technology-intensive growth industries.[27] Cyclical changes resulting from the recessions of 1975 and 1982 may have exacerbated this structural change, which could mark the decline as the turning point for the Manufacturing Belt as the dominant industrial core of the country. However, the position of any region on its growth curve is the result of counterbalancing forces from the push of innovation adaptation, on the one hand, and the pull of inertia protecting existing structures, on the other. Recent studies of the locational concentration of R&D and adoption rates for new production technologies suggest that the old industrial heartland still has more indigenous potential for economic revival than is generally accepted.[28] Evidence from the recent revival of New England is further testimony to this.

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[22] Pred, op. cit., p. 256.

[23] Mansfield, op. cit.

[24] H. J. Ewers and R. W. Wettman, "Innovation-Oriented Regional Policy," *Regional Studies*, vol. 14, 1980, p. 169.

[25] Rees, op. cit. Also, Norton and Rees (1979), and Thomas (1980).

[26] Ibid.

Recently, therefore, it has become popular to think in terms of long cycles (or waves) of growth and decline, but this time in a regional context.[29] The notion of a regional economic lifecycle has its antecedents in Kondratieff's long waves and Schumpeter's notion of "creative destruction," in which new economic structures in new regions bypass existing structures that have become functionally obsolete. Using this framework, New England was the first Frostbelt area to enter a long economic slump, and therefore would be expected to recover first. But one has to treat such generalizations with care. "There are two economies going on in the New England States," according to one view, "the high-tech area but also the continuing struggle of the old mill towns."[30] The large number of part-time and low-wage jobs in the region has led some researchers to view New England as a dual economy with a "missing middle . . . of skilled jobs within particular industries which traditionally employed the largest number of skilled and semi-skilled blue collar workers."[31]

Others are skeptical that the industrial Midwest will go through the same kind of economic transformation as New England, due to inertial factors like high levels of unionization and relatively high wages.

The future direction of the industrial heartland's lifecycle, and the reliance on high-technology industry as the engine of revival, are clearly open to question. The technological imperative that drove the revival of New England may not be present in other areas, at least not to the same degree. However, the industrial heritage of the Manufacturing Belt, the quality of output associated with its companies, and increasing wage inflation in Sunbelt regions may in time shift the comparative advantage back to America's older industrial regions.

Industrial Location Theory and the Location Decisions of High-Technology Companies

Overview

The growth theories reviewed so far deal with regional economic development in a macro sense. Whether or not they are applicable to understanding the location patterns of industry is dependent on the cumulative effect of individual investment decisions and how individual decisionmakers react to their own perceptions of reality. To date, industrial location theory can be divided into two major schools of thought: least-cost theory and maximum-demand theory.[32] Dissatisfied with the unrealistic assumptions of these theories, however, regional researchers have argued that a more appropriate understanding of business location can only be achieved by examining the decisionmaking process in its corporate context.[33]

Selecting the location for a new plant is typically a decision made by relatively few senior executives of a firm, based on the objective and judgmental balancing of corporate goals and a variety of location factors. The location search typically proceeds sequentially: a region of interest is delimited; subsections of the general region are evaluated; towns that meet the minimum requirements for the plant are identified; and finally a specific town is selected and the building site is purchased. The location factors change in relative importance with each change in the geographical scale of the search.

Location factors may be separated into two general types: 1) those relating to the friction of distance, and 2) those relating to the attributes of areas. Friction-of-distance variables are those which measure the costs of moving materials, products, people, or ideas across space. These costs may be measured in terms of miles, or money, or time, or even psychologically as ease or convenience. The second category is concerned not with how far one place is from another, but rather with the characteristics or attributes of the area itself. Included are variables such as labor, agglomeration and infrastructure, power, water, and the quality of life. Specific factors vary in relative importance according to firm, place, and time; each situation is unique. Location theory has traditionally emphasized friction-of-distance variables, but the attributes-of-area variables are becoming more important for many plant location decisions. The factors most often considered relevant, however, are access to markets, access to materials, transportation facilities, labor (especially availability and productivity), utilities, business services, taxes, and local "quality of life."

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[27] R. D. Norton and J. Rees, "The Product Cycle and the Spatial Decentralization of American Manufacturing," *Regional Studies*, vol. 13, 1979.

[28] J. Utterback, 'The Dynamics of Product and Process Innovation in Industry," in *Technological Innovation for a Dynamic Economy*, C. Hill and J. Utterback (eds.) (New York: Pergamon Press, 1979).

[29] G. Sternlieb and J. W. Hughes (eds.), *Revitalizing the Northeast* (New Brunswick, NJ: Rutgers University, Center for Urban Policy Research, 1978).

[30] *The National Journal*, Feb. 26, 1983, p. 436.

[31] B. Harrison, "Rationalization, Restructuring and Industrial Reorganization in Older Regions: The Economic Transformation of New England Since World War II," Working Paper #72, Joint Center for Urban Studies, MIT-Harvard University, 1982, p. 117.

[32] Lloyd and Dicken, op. cit. Also Smith (1980).

[33] H. A. Stafford, *Principles of Industrial Facility Location* (Atlanta: Conway Publications, 1980).

The Location Factors That Influence High-Technology Industry

The popular concept of high-technology industry most closely corresponds to firms or plants that produce high-technology products. Compared with most manufacturing companies, these firms tend to be relatively small and new. In conducting site searches, they are likely to engage in an informal, top-down style of decisionmaking (due to the lack of internal specialists) and have limited search spaces, preferring to locate new activities close to existing operations.[34]

Friction-of-distance factors are relatively unimportant, because they manufacture high value-added products for which unit transportation charges are low, because their input materials come from a variety of sources and locations, and because their markets also tend to be spatially scattered.

Table A-1 indicates the relative significance of the 10 most important location variables according to various ranking schemes, by high-technology and non-high-technology plants, and by location decisions at the regional and within-region scales.

Labor.—Labor stands out as the most important location determinant in the search for a new plant site. This is especially so for high-technology plants: a recent survey found that 79 percent of high-technology decisionmakers mentioned labor as an important factor in their selection of a branch plant location and this was the only factor mentioned in more than half the location decisions.[35] In an earlier survey conducted by the Joint Economic Committee (JEC) of Congress, fully 89 percent of the respondents indicated that labor skills and availability were "significant" or "very significant" at the regional scale, with 96 percent the comparable figure at the within-region scale.[36]

While labor costs are of some importance, it appears that the availability, attraction, and retention of skilled technical and professional personnel are the primary con-

Table A-1.—Location Factors Influencing New Manufacturing Plants

Determinants for high-technology v. non-high-technology plants

Rank	High-technology plants	Non-high-technology plants
1	Labor	Labor
2	Transportation availability	Market access
3	Quality of life	Transportation availability
4	Markets access	Materials access
5	Utilities	Utilities
6	Site characteristics	Regulatory practice
7	Community characteristics	Quality of life
8	Business climate	Business climate
9	Taxes	Site characteristics
10	Development organizations	Taxes

SOURCE: H. A. Stafford, Survey of 104 Plants, 1983.

Determinants for high-technology plants between and within regions

Rank	Selection of region	Selection within region
1	Labor skills/availability	Labor availability
2	Labor costs	State/local tax structure
3	Tax climate within region	Business climate
4	Academic institutions	Cost of property/construction
5	Cost of living	Transport availability for people
6	Transportation	Ample area for expansion
7	Markets access	Proximity to good schools
8	Regional regulatory practices	Proximity to amenities
9	Energy costs/availability	Transport facilities for goods
10	Cultural amenities	Proximity to customers

SOURCE: Joint Economic Committee, U.S. Congress, *Location of High Technology Firms and Regional Economic Development*, June 1, 1982, tables III.5 and 6, pp. 23 and 25.

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[34] R. Oakey, A. Thwaites, and P. Nash, "The Regional Distribution of Innovative Manufacturing Establishments in Britain," *Regional Studies*, vol. 14, 1980.

[35] Stafford, op. cit.

[36] Joint Economic Committee, U.S. Congress, *Location of High Technology Firms and Regional Economic Development* (Washington, DC: U.S. Government Printing Office, June 1982).

cerns when high-technology firms locate or expand production facilities. Even highly skilled labor tends to exhibit a significant degree of spatial inertia; in this sense, high-technology industries are not truly "footloose," because they are constrained by the uneven distribution of relatively immobile labor. As a result, the R&D centers of large corporations are most often located in urban areas that are rich in information, skills, and management.[37]

Academic Institutions.—Several studies have indicated the importance to high-technology industries of nearby colleges and universities, especially those that focus on scientific and technical education. These educational institutions are directly influential because they are repositories of technical information and they train the needed engineers and technicians. They also are important in attracting and retaining skilled workers who want continuing educational opportunities. Furthermore, to the extent that new high-technology firms are spinoffs from existing enterprises, they are more likely to be born and survive in the technology-rich environments spawned by nearby universities. The importance of nearby academic institutions is consistent with the overwhelming locational importance of skilled labor, as are the quality of life and cultural amenities variables.[38]

Quality of Life and Amenities.—For all industries, the human factor has become a more important locational variable in the past two decades. For some it has meant a search for low-cost labor areas, but for high-technology industry it means areas that, because they are attractive to highly skilled workers, are thereby more productive environments. Quality of life and the existence of sufficient amenities, both cultural and recreational, are difficult variables to measure, but there is little doubt that they are critical in locational decisions.[39] In table A1 these include not only "quality of life" and "proximity to amenities," but also "academic institutions" and "proximity to good schools." A plant started in a community which ranks low on the livability scale will soon have difficulty in attracting, or even transferring, engineers and managers.[40]

Access to Markets, Materials, Transportation, and Agglomeration.—Industrial location theory has traditionally emphasized the costs of moving materials to the plant and products to the consumers. These friction-of-distance considerations are relatively unimportant for high-technology firms, which produce items for which transportation costs are a small proportion of delivered price; transit time is more critical than cost. They also utilize a wide variety of inputs which are not conveniently localized, so the advantages of locating near one supplier are neutralized by the distances from others. Transportation is, however, a factor of some locational importance, but more in terms of the requisite modes and frequency: high-technology firms need easy access to high-level, rapid transportation facilities (e.g., air travel) for the movements of managerial and technical staff. Market access is a variable of moderate importance to high-technology plants, but again the emphasis is on ease and speed rather than cost. Access to customers is more important when the sale contract calls for service or when there are significant reciprocal information transfers.

Taxes.—No issue is more debated in the industrial location literature than the influence of taxes on site selection. Decisionmakers frequently mention the importance of regional and local tax differentials in their location decisions, but analysts usually conclude that taxes are of relatively little importance, especially when regions of interest are being determined. One consultant suggests that industrialists often use taxes as rationalization for opposing labor unions and other costs, real or imagined, associated with an unsatisfactory regional image; based on his company's studies, the consultant concludes that "it is apparent that in every case State taxes are the least significant of all factors."[41] Other researchers have also concluded that taxes are a relatively minor locational variable, and that taxes are often as much an emotional issue as a financial one.[42] Low taxes may be somewhat more valued by high-technology industries since they are less locationally constrained by other factors.[43] The JEC survey indicates that taxes are the second most important locational determinant for high-technology firms, ranked "very significant" or "significant" by 67 percent of respondents at the regional scale, at the within-region scale rising to 85 percent.[44] A more recent survey, however, places taxes as a minor locational variable: only 14 percent of the high-technology respondents even mentioned taxes as a location factor.[45] The issue remains unresolved, but further complications are introduced when it is noted that low taxes usually are negatively correlated with several other attributes which high-technology firms value, including public services, infrastructure, good schools, and cultural amenities.

Financial Capital.—Although access to financial capital is a key variable in R&D trends and innovation generation, very little is known about geographical differences in its availability. Industrial location literature traditionally assumed uniform accessibility to financial capital, and this assumption has become part of the common wisdom without appropriate empirical testing.[46] Given the different banking systems in the United States, ranging from branch banking to unit banking as modified by multibank holding company acquisitions, the assumption is probably faulty, particularly in the current context of deregulation in the financial sector.

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[37] E. Malecki, "Corporate Organization of R and D and the Location of Technological Activities," *Regional Studies*, vol. 14, 1980.

[38] E. P. Deuterman, "Seeding Science Based Industry," *New England Business Review*, 1966. Also Gibson (1970), and Joint Economic Committee (1982).

[39] Stafford, op. cit., p. 100.

[40] R. Schmenner, *Making Business Location Decisions* (Englewood Cliffs, NJ. Prentice-Hall, 1982), p. 38.

[41] H. L. Hunker, *Industrial Development* (Lexington, MA: Lexington Books, 1974), p. 139.

[42] Schmenner, op. cit. Also, Stafford (1980), p. 109.

[43] Ibid., p. 50.

[44] JEC, op. cit.

[45] Stafford, op. cit.

Because of the importance of venture capital in the generation and commercialization of innovations, particularly by small companies with higher risks attached to them, regional and temporal variations in access to capital may be a more significant factor than has been shown. For example, a recent study of the financing difficulties encountered by 2,000 companies found that smaller firms have more difficulty than larger firms and rural companies have greater difficulties than urban or suburban firms; but when firms were aggregated by census region, there were few discernible differences in their difficulties in obtaining capital.[47]

Applying Theories to High-Technology Development Programs

Because of the increasing involvement of States and local communities in intense competition for high-technology plants and jobs, it has become even more important for them to be aware of location factors that industrial decisionmakers consider important. Above all, they must assess their region's attributes in a realistic fashion and then match them up with the factors valued by industry, as part of their economic strategy in their area development programs.

The Need To Assess and Mobilize Local Potential

There will be intense competition over the next few years for a few selected high-technology industries, and the job creation potential at the end may still be low. Because the rewards may be small and the game highly competitive, each locality needs to assess its existing potential in order to establish realistic goals for attracting high-technology industries. One of the most effective tools for this purpose is the "target industry screening method" developed by the Battelle Institute in 1970.[48] Developed as an alternative to the "shotgun approach" of many community marketing efforts, the screening matrix method provides a more systematic way of matching the attributes of a community with the needs of an industry.[49] This approach assumes that it is important for future industry to be related to the existing economic structure of an area in terms of industry linkages and resource base. This implicitly recognizes the importance of current attributes in attracting further development, as explained by export base and growth center theories described above.

After careful consideration of an area's comparative advantages and current economic conditions, industries whose location criteria most nearly match the community's attributes are identified as the highest order prospects for its recruitment efforts.

The types of locational criteria that should enter the screening methodology in the context of high-technology industries should include the following factors discussed in earlier sections:

- *The existing economic base,* particularly the presence of high-technology sectors or companies with direct links to high-technology sectors. This approach could include input-output analysis and would identify potential industries for import substitution.
- *The scientific and technical environment,* including access to major universities and research institutions.
- *Labor factors,* including occupational mix (proportions of professional, skilled, and unskilled workers), labor cost, and productivity as they relate to the labor intensity of existing industry.
- *Financial variables,* including local property and income tax rates, the role of commercial banks and savings and loan banks, and the presence of other financial institutions with access to development capital.
- *Amenities,* particularly access to recreational and cultural opportunities.
- *Access to local and national markets* via different forms of transportation.

Only through systematic assessment can the community assess its comparative advantage for attracting specific industries. A regional marketing plan should, however, look out for conflicting goals. For example, it is conceivable that industries with a high propensity to attract suppliers (backward links) may result in the clustering of firms that could put excessive demands on certain types of labor. This in turn could result in higher rates of wage inflation in the area, which could prove unattractive to other industries. An understanding of an area's industrial base, plus an objective screening process, is one of the few sound ways of attracting future economic development, whether technology-intensive or not. Without such systematic procedures, community resources may be wasted.

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[46] D. M. Smith, *Industrial Location* (London: John Wiley, 1980).

[47] M. Katzman, "The Case Against Bailing Out Distressed Areas," in *Public Policies for Distressed Areas,* S. Redburn and T. Buss (eds.) (Lexington, MA: Lexington Books, 1982), p. 33.

[48] Battelle Institute, *The Regional Potential Model* (Columbus, OH: Battelle Memorial Labs, 1970).

[49] D. C. Sweet, "An Industrial Development Screening Matrix," *Professional Geographer,* May 1970.

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APPENDIX B

Formation and Growth in High-Technology Firms: A Regional Assessment*

Summary

Recent publicity about rapid growth of employment in high-technology industries has caught the attention of policymakers at all levels of government. Many State and local governments have already created programs to encourage location of new high-technology businesses in their regions. While there is no shortage of policies promoting emphasis of local development efforts on encouragement of high-technology industries, there is a dearth of empirical information on the efficacy of such programs. This study attempts to provide an empirical description of the high-technology sector, its regional growth patterns, and the relationship of particular characteristics of metropolitan areas to high-technology growth.

A large business microdata set, the U.S. Establishment and Enterprise Microdata (USEEM) files has been developed at The Brookings Institution for the Small Business Administration with additional support from the National Science Foundation (NSF). Several properties of this new data set recommend its use for this type of analysis. Most important is the facility to specify groups of business establishments and examine details of their behavior over time, differentiating—e.g., business formations, closures, expansions and contractions. The presence of information on organizational status of establishments (e.g., whether an establishment is a branch of a larger business or an independent enterprise) permits the analysis of the employment changes in establishments within the context of their owning enterprises.

Adopting a broad, but rigorous, definition of high-technology industries, based on minimum levels of professional, scientific, and technical workers in each industry or of research and development (R&D) expenditures, tabulations of matched records from the USEEM files for 1976 and 1980 were prepared to provide data to analyze the size and distribution of the high-technology sector in 1976 and its growth from 1976 to 1980.[1] Data for the high-technology sector are contrasted with that for the rest of the manufacturing and business service industries (called "low technology") and with that for "other industries" (excluding manufacturing, business services, and government). Employment growth and business formation data were extracted from these tabulations and integrated with other socioeconomic data for a sample of 35 metropolitan areas. These aggregate data were then used in a regression analysis examining the relationships between the characteristics of the metropolitan areas in the sample and the formation and growth of both high-technology and other business establishments.

The descriptive analysis of the tabulations and the regression analysis addresses the following questions. What are the characteristics of high-technology establishments and their patterns of employment growth? How does the distribution and behavior of high-technology establishments differ from that of establishments in other industries? Are high-technology industries dominated by large corporate enterprises, or do independent establishments flourish in the atmosphere of innovation and growth? Firms in these industries are subject to ever-shortening technological lifecycles requiring them to innovate or die. Which establishments are succeeding in their pursuit of change and growth?

While this analysis is not designed to demonstrate cause and effect relationships among these factors, it provides important baseline data on the magnitude, location, and growth of firms in the high-technology industries. In addition, the analysis advances the discussion of the sources of employment growth by testing many popular hypotheses against actual data for the period 1976-80 and by reformulating several hypotheses consistent with the evidence.

The High-Technology Sector

Although the high-technology sector, as defined in this study, included only 2 percent of the business establishments in the United States in 1976, it accounted for 7.4 percent of all private sector employment. High-technology industries comprised 11 percent of establishments, with 21 percent of the employment in manufacturing and business services in 1976. The average size of high-technology establishments (69 employees) is more than twice that of the low-technology manufacturing and business services and five times the average establishment size in "other industries."

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[1] This definition of the high-technology sector included 88 industries in manufacturing and business services, most of which rely heavily on evolving technologies.

Almost 90 percent of high-technology jobs are in firms with at least 100 employees, compared to the national average of 64 percent. Furthermore, the organizational composition of the high-technology sector is heavily skewed toward branches of large firms. More than 88 percent of the jobs in high-technology industries are in multiestablishment firms.

The distribution of high-technology jobs across four broadly defined regions of the United States is generally the same as that of employment in all industries. The Northeast has 29 percent, the North Central has 28 percent, the South has 24 percent, and the West has 19 percent. Diverging from the other regions, the South's high-technology employment is disproportionately in affiliates of firms whose owners are located in different States.

In sum, the high-technology industries comprise a relatively small sector of the economy, concentrated in large branch establishments of multiestablishment firms. Half of the employment is in affiliated establishments which are owned and operated by headquarters located in different States, which are frequently engaged in more than one major industrial activity. The regional distribution of high-technology employment is much the same as that of employment in all industries.

Regional Growth Patterns

The previous section has provided a "snapshot" of the current status of high-technology firms in the United States. It is also important to identify trends or changes in that status by evaluating the formation and growth patterns in these industries. Are these reinforcing or restructuring the established profile of the high-technology sector? High-technology industries exhibited two important characteristics in the broad regional assessment: 1) they have generally high employment growth rates, and 2) differences in regional growth rates tend to offset existing inequities in the distribution of employment in high-technology and in other industries.

Employment in high-technology industries in the United States grew a total of 19.5 percent between 1976 and 1980, an average annual growth rate of 4.5 percent compared to the all industry rate of 3.6 percent. The percentage employment growth rate in high-technology industries was a third higher than in the low-technology part of the manufacturing and business services. Of the net increase in private sector employment between 1976 and 1980, high-technology industries contributed 9.5 percent, about 30 percent more than its 7.4 percent share of employment in 1976.

Within each of the four regions, the growth rate of high-technology employment exceeded that of the other two industrial sectors. The discrepancy was greatest in the South where high-technology employment increased at a rate almost twice the overall average. However, the interregional differences in high-technology growth rates followed the same general pattern as growth rates for other industrial sectors. In other words, the distribution across regions of high-technology growth did not differ markedly from that of other industries.

The regions which experienced the highest rates of growth were those which previously had the smallest shares of high-technology employment. Although the South and the West held only 43 percent of the total employment in high-technology in 1976, these two regions accounted for 70 percent of that sector's growth between 1976 and 1980. This distribution of growth in high-technology employment roughly paralleled that in all industries, indicating a general trend towards equalizing the distribution of both high-technology and other business activity across regions of the United States.

Formations of new business establishments are a major component of net employment change. Within each region, the formation rates for the high-technology sector range from 30 to 50 percent higher than those for the "other industries" sector. Low-technology formation rates were almost identical to those of the "other industries" sector in the Northeast and the North Central regions, but were stronger than "other industries" in the South and West.

During the 1976-80 period, a region's shares of formations and its shares of associated new employment were nearly the same for each of the three sectors. This share was 19 percent for the Northeast, 23 percent for the North Central, 34 percent for the South, and 24 percent for the West. Consistently, the Northeast and North Central had formation rates below the U.S. average for all three of these industry groupings while the South and West had above average rates, of both business and job creation.

Rates of job loss from closings and contractions were similar across regions. Much of the decline in the older industrial regions was attributable to lower rates of formation of new business establishments. Therefore, it is not surprising that the regional differences in formation rates are quite similar to differences in the rates of net employment change. Again the tendency toward a redistribution of economic activity is reducing the skewed nature of existing distributions.

A shift share analysis of manufacturing employment growth, which separates employment growth into components attributable to national (average) growth, regional (competitive) differences, and industrial composition (mix) differences, revealed some interesting aspects of regional growth patterns between 1976 and 1980. Looking first at the regional, competitive component of employment change, the negative impact of the Northeast's languishing economy was so large that its net growth was only one-third as high as it would have been if the regional economy had performed as well as the national average. The region suffered below average growth rates in every industrial sector. Both the South and the West were strong in all industrial sectors, but the West was almost twice as strong as the South.

Industrial composition effects were more startling, especially compared to those found in similar analyses of manufacturing employment growth between 1963 and 1972 and between 1972 and 1976.[2] While the Northeast used to have a a large enough share of high-growth industries to more than offset its very high share of low-growth manufacturing, the mix in the 1976-80 period was just barely balanced. This trend of decreasing advantage of industrial mix is even stronger in the North Central region.[3] The South continues to have a relatively small share of the high-growth industries, in spite of its overall excellent economic health. Restating the point made above, although the South had by far the highest growth rate for high-technology business, it had the smallest proportion of high-technology employment.

Regional differences in employment growth were attributable more to general regional economic performance than to specific differences in industrial composition in the shift share analyses for each of the periods between 1963 and 1980. Consistent with these findings, it has recently been suggested that the major problem issuing from the economic changes of the 1970's is not "one of declining industries or declining competitiveness but one of declining places."[4] The decline of certain industries concentrated in the North and its relative loss of population would not be so important if other industries were moving in to take up the slack. As pointed out above, the Northeast had the lowest formation rate in all three industrial sectors affording insufficient counterweight to employment losses in its declining industries. The general weakness of the Northeast's economy has been exacerbated by an erosion, during the past two decades, of its previously advantageous industrial mix. The West, on the other hand, is developing an increasingly favorable industrial mix, with a disproportionately large share of high-growth, high-technology industries, buttressing its strong regional performance.

High-Technology Formations in Metropolitan Areas

To better understand these regional patterns of high-technology development a more detailed analysis of formation and employment growth in metropolitan areas was conducted. Business formations constitute an important, if not determinant, force in net employment growth. Through a regression analysis of business formation rates on several metropolitan characteristics, it was hoped that certain policy relevant relationships might be unearthed.[5]

It was hypothesized that each of the dependent variables would be related to some or all of the following factors:

- the pool of potential entrepreneurs,
- the relative costs of doing business,
- the level of activity in that industrial sector,
- regional economic conditions,
- the quality of the labor force, and
- general attractiveness of the city.

Business formations were expected to have strong positive associations with the pool of potential entrepreneurs, the economic health of the area, the general attractiveness of the area, the quality of the labor force, and the level of extant activity in the same industrial sector. Only the costs of doing business were expected to be negatively related to formations.[6] The relative attractiveness of the city both to people and to business, as measured by the rate of population growth in the first half of the 1970's, was the factor most strongly associated with metropolitan differences in formation rates. Each difference of 1 percent in the total population growth rate was associated with close to a 4-percent difference in the rate of business formations in both high- and low-technology sectors. There was a corresponding 2.5-percent difference in formations in the "other industries" sector.

Another proxy for attractiveness of the city and cultural amenities, city size (1975 population), was also associated positively with both high- and low-technology business formations, even after using total labor force as a normalizing variable. Each 4-percent difference in city size was associated with a 1-percent difference in the number of business formations in both the low- and high-technology sector.

Three measures of business costs were included: wage rates, electricity costs, and local taxes. Each of these variables was related negatively to formation rates in every industrial sector, when differences in population growth were not taken into consideration. Their explanatory power was strongest in the low-technology sector, followed closely by the high-technology sector, and finally by the "other industries" category.

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[2] See John Rees, "Regional Industrial Shifts in the U.S. and the Internal Generation of Manufacturing in Growth Centers of the Southwest," in *Interregional Movements and Regional Growth,* William C. Wheaton (ed.) (Washington, DC: The Urban Institute, 1981).

[3] The negative industrial mix components affecting the northern regions is probably understated due to the level of aggregation of the industrial sectors used here. This analysis uses only three industrial sectors as mix components: 1) high-growth, high-technology industries; 2) low-growth, high-technology industries; and 3) low-technology industries or "other manufacturing and business services."

[4] Shirley P. Burggraf, "Overview and Critique of Revitalization Issue," *Policy Studies Review*, vol. 2, No. 4, May 1983, p. 674.

[5] For analyzing metropolitan differences in business formations, the actual number of formations should be scaled by some measure of the size of the area's economy to create easily comparable formation rates. Preliminary regressions on the number of formations confirmed that the size of the total local labor force was a more appropriate scale factor than the number of businesses.

[6] Description of the various indicators adopted as proxies for these factors is provided below.

As expected, differences in local economic conditions were reflected roughly proportionately in differences in formations in each industrial sector.[7] However, the high-technology sector was somewhat less sensitive than the other two sectors to local economic conditions.

The existing literature on high-technology firms postulates a more specific link between their formation and growth and such variables as the availability of technical and scientific workers or the presence of an extant, healthy high-technology sector. As hypothesized, a significant positive relationship was found between technical skills and formation rates in high-technology industries. A 1-percent difference in the technical occupation share of the labor force was associated with about 2-percent difference in formation rates. Though positive, the relationship was only half as strong for the low-technology manufacturing and business services sector. For the "other industries" sector, the relationship was negative and insignificant.

It is frequently assumed that there is a large agglomeration effect in formations of high-technology businesses. That is, new businesses will tend to locate near extant successful firms in the same industry in order to take advantage of the established pools of support services and of trained workers and managers. There was no measurable association of high-technology formations with the share of local employment in high-technology industries. Nor was there a discernible relationship with the absolute size of the high-technology sector, which would have indicated that spinoffs from existing businesses contributed significantly to total formations. These two expected relationships might be measurable with less aggregated industrial groupings.

Finally, two firm size classes were considered in this analysis: tiny firms (fewer than 20 employees) and large firms (100 or more employees), representing divergent organizational types, as well as size classes. Tiny firms are primarily independent businesses (single-establishment firms) and are usually founded in the city where their entrepreneur resides. Therefore, tiny high-technology formations were expected to be more sensitive than large firm formations to intermetropolitan differences in the supply of potential high-technology entrepreneurs (share of work force in scientific and technical occupations) and to differences in local economic conditions (employment rate and overall growth rate). Large firm formations are usually branches of existing enterprises, which are more likely to base their location decisions on relative business costs (wage, tax, and utility rates), on availability of an appropriate labor force, and on the general attractiveness of the area (previous period population growth).

For both size classes the relationships of formations to each of the independent variables were generally of the expected direction. Tiny firm formations were indeed more sensitive to the measure of technical skills than were large firm formations. They were also more sensitive to variations in the measures of business costs, which were statistically significant only for formations of tiny firms. Compared to large firm formations, a larger portion of the total variation in tiny firm formation rates was explained by the metropolitan characteristics. Contrary to expectation, the strength of the local economy, as measured by overall employment growth, was not significantly related to high-technology formations in either size class. It was significantly related to formations in the low-technology sector.

Metropolitan Characteristics Associated With Employment Growth

Net employment growth in a sector is a rather volatile concept. It is usually a small number which represents the balance between a large positive amount (new jobs from business formations and expansions) and a large negative amount (jobs lost due to closings and contractions). Rates of job loss are more similar across regions than rates of job gains, so the analysis of net changes is primarily the analysis of differences in formations and expansions. Though influenced by many of the same factors, decisions to expand or contract employment in existing facilities generally reflect location decisions of earlier periods and current fluctuations in economic conditions. In view of this, separate equations were formulated using the rates of net employment growth, for each of the three industrial sector between 1976 and 1980 as the dependent variable.[8]

Not surprisingly, many of the factors observed to be important in explaining differences in business formation rates are also significant in explaining differences in employment growth rates. In the high-technology sector, growth rates were more sensitive to variations in metropolitan characteristics than in the low-technology or "other industries" sectors. The level of education and technical skills in a metropolitan area was closely associated with differences in high-technology growth rates, but not with those of the low-technology nor the "other industries" sectors.

An interesting small, but consistent and significant, negative association was found between growth rates and sector shares. In other words, in locales where the high-technology sector had a relatively large share of total local employment, its growth rate was somewhat lower than average. For each 3-percent (not percentage points) increase in the employment share of the high-technology sector, its growth rate was 1 percentage point lower. Low-technology and "other industries" were only half as sensitive to sector share size differences, but they were still negatively related.

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[7] Measures of current economic conditions used were the SMSA's employment rate in 1976 (one minus the unemployment rate) and overall employment growth (1976-80).

[8] Employment growth rates were measured as the ratio of 1980 sector employment to 1976 sector employment, or the difference between the logarithms of 1980 and 1978 employment.

Tiny firm employment growth rates in both high- and low-technology industries were generally much higher than those of large firms. While the relationships between large firm formations and the business cost variables were not significant, large firm employment growth did exhibit a significant negative relationship to the business cost variables. Employment growth rates of existing tiny firms are generally less sensitive than large firm rates to all significant metropolitan variables.

Employment growth in large high-technology firms is particularly responsive to variations in the strength of the local economy and in the supply of technically skilled labor. More notably, large firm growth rates in the high-technology sector show a significant negative association with sector share, while tiny firm growth was virtually independent of that factor. Again a disaggregation to the four-digit industry level might reveal an agglomeration effect for either size class.

Introduction

Purpose

Concern engendered by the recent recession and persistent high levels of unemployment has produced a mass of local, State, and Federal programs which attempt to use "high technology" as a solution to many economic ills.

These programs hope to provide a new era of growth spawned by the emergence of new industries and the transformation of traditional manufacturing industries through technological innovation. Concurrent with the popularization of this prescription for economic health, almost every State government has created or considered creating programs to encourage innovation and the formation of high-technology firms. Policies and programs with similar objectives at the Federal level have also been proposed to Congress. The few highly publicized locales, such as "Silicon Valley" in California and Route 128 in Massachusetts, which have benefited from the rapid development of the electronics industry in the last decade, have become the paradigms for economic growth or recovery for many cities in the Nation.

As is often the case, the advocacy of policy changes has proceeded more quickly than the accumulation of empirical information on which to base these policies. Whether attempts to imitate known concentrations of high technology are either feasible or desirable is a question that economists and policy planners are not yet prepared to answer. Too little is known about the innovation process, the formation decisions of new firms, the plant location decisions of large firms, the dynamics of product development, the connections between high-technology firms and other firms which form complex supplier-customer relationships at both the local and the national level, and the effectiveness of alternative strategies for promoting such development.[9]

Most previous attempts to investigate the interaction of innovation, formation of high-technology businesses and regional economic development have been very limited in scope—focusing on single industries, specific communities or a single factor among the many which may encourage innovation and growth. Neither the analysis of the aggregate behavior of all businesses in an industry nor studies of single businesses can provide much useful guidance. The relevant unit of analysis is a group of establishments or firms with similar characteristics of economic behavior. The missing body of knowledge might be termed "industrial group dynamics"—the medium-term behavior of business establishments grouped by industry, region, size, firm structure, age, and other such factors.

The objective of this current undertaking is to provide a better foundation for the assessment of the potential of high-technology firms to increase local employment and for the design and implementation of policies to maximize that contribution. Through comparative analysis of regional patterns of location and growth of firms in high-technology industries contrasted with other industry sectors, this study attempts to identify special characteristics of high-technology businesses, of its new firms and branch establishments, and of the communities in which they choose to locate.

Data Resources

Until recently, policy analysts and scholars who have tackled questions in this area of industrial group dynamics have been severely limited by the lack of appropriate data. Thus, their investigations must either start with the collection of basic data by surveying a small sample of businesses or be limited to the factors distinguishable in cross-sectional aggregate data on businesses.

The recent development of a very broad microdata base for U.S. business establishments now provides the flexibility in aggregation which is needed to construct appropriate statistical bases for analysis of the dynamics of industrial groups. The USEEM files have been developed at The Brookings Institution for the Small Business Administration with additional support from NSF. Each file represents a reasonably complete census of U.S. business establishments with employees, with data on industrial activity, employment, location, age, and organizational status and on characteristics of its owning firm if it is part of a multiestablishment enterprise. The USEEM files now cover 1976, 1978, 1980, and 1982, but weighted longitudinal data for analysis of changes in the U.S. business population are available only for the 1978-80 and the 1976-80 periods.

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[9] For a review of the state of the art, see Louis G. Tornatzky, et al., *The Process of Technological Innovation: Reviewing the Literature* (Washington, DC: National Science Foundation, May 1983).

Several properties of this new data set recommend its use for this type of analysis. In particular, the detailed standard industrial classifications (four-digit SIC) in these microdata will eliminate some of the more significant problems of aggregation afflicting the definition and analysis of the high-technology sector.

A related major feature of this data base, in fact its raison d'etre, is the facility to specify groups of business establishments and examine their behavior over time. The presence of information on organizational status of establishments (e.g., whether an establishment is a branch of a larger business or an independent enterprise) permits the analysis of the growth behavior of establishments within the context of their owning enterprises.[10] Not only are the basic descriptive characteristics of the owning enterprise available (e.g., employment size and predominant industrial activity), but also the location of the enterprise headquarters. This allows the employment growth resulting from local initiative to be distinguished from that attributable to the location and expansion decisions of larger, multiestablishment enterprises. A discussion of the basic data and its aggregation into the high-technology growth tables and Metropolitan Area Aggregate Data Base is found below.

Scope of Analysis

In order to develop a comprehensive perspective on the nature of high-technology firms and their role in regional economic development, certain questions must be systematically addressed. First, what is a "high-technology" industry? To many State and local development officials, it simply means any industry using electronics which has high growth potential, preferably employment growth. For the more rigorous demands of empirical research, the definition of high technology must encompass the notion of innovation in products and processes, accompanied by relatively large expenditures on R&D performed by a cadre of scientific and technical personnel. Recognizing that any definition of high technology based on groups of firms by industrial classification is flawed, this study uses an explicit minimum on the proportion of scientific, engineering, and technical personnel relative to total staff or of R&D expenditures to sales as the criteria for "high technology." This criterion identifies 29 of the 158 three-digit standard industrial classes in manufacturing and business services as the "high-technology" sector. These are broken out into 88 four-digit classes, which are further discussed below.

Given this definition of high-technology industries, what are the characteristics of high-technology establishments and their patterns of employment growth? How does the distribution and behavior of high-technology establishments differ from that of establishments in other industries? Are high-technology industries dominated by large corporate enterprises, or do independent establishments flourish in the atmosphere of innovation and growth? Which kinds of establishments are succeeding in the pursuit of growth?

Tabulations of the USEEM files provide important descriptive information on the magnitude, location, and growth of firms in the high-technology industries, which can be used to answer these basic questions. Changes in establishment populations and employment and data for business formations are detailed for high-technology industries and for two comparison groups of non-high-technology industries by various categories of business characteristics.

For example, one popular assumption is that growth within the high-technology sector is concentrated in small, independent businesses, operated by dynamic entrepreneurs.[11] In order to examine this aspect of high-technology development, types of establishments were distinguished in the tabulations as follows: independent firms, owners of other establishments, affiliates (branches and subsidiaries) of local (instate) firms, and affiliates of national (out-of-State) firms. Establishments were also classified by three enterprise (firm) employment size classes: under 20 employees, 20 to 99 employees, and 100 or more employees. In addition to totals for the United States, information has been compiled for a sample of 35 Standard Metropolitan Statistical Areas (SMSAs) and for the four major economic regions of the United States—the Northeast, the North Central, the South, and the West. Patterns of high-technology development across the four broad regions are discussed in general and with reference to these various categories of business.

In the next part of the analysis the information on business formations and employment growth in high-technology industries for each of the 35 SMSAs is analyzed in relation to the socioeconomic characteristics of these metropolitan areas. While this regression analysis is not designed to demonstrate causal relationships, it advances the discussion of the sources of employment growth by providing accurate empirical data on high-technology development and noting the association or lack of association between that development and certain metropolitan characteristics. Similarities and differences in the patterns of high-technology development are again compared to the patterns in the rest of manufacturing and business services ("low-technology") industries and in all other industries. Finally, this analysis considers two different employment size classes and reveals some interesting differences in the behavior of small independent firms and that of establishments which are part of larger firms.

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[10] Implicit in such an analytic breakdown is the need to distinguish between *enterprises* (i.e., the legal and economic entity or "firm," including affiliates) and *establishments* (i.e., geographically distinct operating units either independent or tied legally and financially to a larger entity).

[11] David L. Koch, William Cox, Delores W. Steinhauser, and Pamela V. Whigham, "High Technology: The Southeast Reaches Out for Growth Industry," *Economic Review*, Federal Reserve of Atlanta, September 1983, p. 4.

Data Sources and Organization

Overview

Previous attempts to analyze the interaction of innovation, the formation of high-technology businesses and regional economic development have been very limited in scope. The most common units of analysis employed in such studies have been either single industries, specific communities, or a single factor among the many which may encourage innovation and growth. The relevant unit of analysis in this field is actually the particular sets of firms or establishments exhibiting similar economic behavior. To focus on the behavior of business establishments classified by certain industrial, geographic, or organizational characteristics, we must have access to data with the appropriate flexibility and level of disaggregation. Microdata on the status and behavior of individual businesses, or very narrowly defined groups of businesses, over time serves this purpose. In addition to enabling us to identify the specific components of growth which constitute the net changes in the business population and employment levels, only microdata permit the accurate measure of change attributable to sets of businesses whose characteristics change over time. Comparisons of cross-sectional aggregate data not only mask the components of change, but seriously distort the apparent behavior of groups of businesses that shift from one category to another between observations.

The remainder of this section describes our primary data source, the U.S. Establishment and Enterprise Microdata Base, and the means by which it was transformed and supplemented for this analysis. From the original data, a condensed longitudinal data base was first constructed to permit efficient data processing of employment and population change data for the 1976-80 period. This condensed data base was then used to generate summary tables of descriptive data for metropolitan and regional areas. Finally, aggregate figures on employment, employment change, and business formations were extracted from the summary tables and merged with various indicators of socioeconomic characteristics of metropolitan areas derived from other statistical sources to form a Metropolitan Area Aggregate Data Base. This Metropolitan Area Aggregate Data Base was used in conducting the regression analyses on factors associated with the formation and growth of high-technology firms in particular areas of the United States.

U.S. Establishment and Enterprise Microdata Base

Our capacity to explore the location and growth of high-technology firms is dependent on our access to and familiarity with the USEEM base, which was developed at The Brookings Institution with support from the Small Business Administration and NSF.[12] Derived from Dun & Bradstreet's DUNS Market Identifiers files, the USEEM have been restructured, edited, and supplemented with data from other sources. They now contain information for individual business establishments (i.e., geographically distinct operating units), which are linked to enterprise data for their owning firm (i.e., the legal and economic entity, including branch and subsidiary establishments). Consequently, these microdata allow us to analyze not only aggregate trends in industry groups, but to identify the characteristics and track the behavior of particular firms or types of firms within an industry (e.g., by employment size, ownership, etc.).

Providing a virtual census of U.S. businesses with employees, USEEM files currently span 6 years. They contain records for 4.2 million business establishments in 1976, increasing to 5.5 million in 1982. The data files can be processed separately for cross-sectional analysis or longitudinally, matching records for each establishment across files. In developing the USEEM files, apparent errors were corrected and missing variables were imputed where possible. For example, employment figures for the 2 to 3 percent of establishments that did not report that data were estimated by calculating median employment levels by State and four-digit standard industrial classes using the Bureau of Census' *County Business Patterns* data.

Perhaps most importantly, a major effort was undertaken to reconcile various indicators of organizational status, relational pointers, and employment figures between member establishments of multiestablishment enterprises. In other words, a "family tree" was constructed for each business enterprise, containing every branch and subsidiary within the legal firm. These family trees were then analyzed to assure completeness and consistency in their hierarchical structures. Having ascertained the proper structure of each complex business, the two employment figures provided (one for each establishment and one for the enterprise as a whole) could then be analyzed for consistency. Discrepancies between the aggregated establishment employment and the reported firm employment were then corrected by: 1) increasing the enterprise employment to reflect the total of all affiliated establishments; or 2) imputing proxy branch establishments to represent affiliates suggested by the total enterprise employment, but not reported.[13]

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[12] For a detailed description of the USEEM data base see Candee S. Harris, *U.S. Establishment and Enterprise Microdata (USEEM): A Data Base Description*, Business Microdata Project, The Brookings Institution, June 1983.

For longitudinal analysis, more extensive editing is applied. Deficiencies in the original data set recommend caution in defining those records which represent accurate measures of employment change over time. The most important problems affecting longitudinal analysis can be categorized as follows: 1) a large portion of the file is not updated between observation years; 2) a few records exhibit unreasonable rates of employment change, indicating possible coding errors; 3) there is a lag in registering business formations and closings; 4) coverage is incomplete, but expanding in certain industries; and 5) proxy records obviously cannot be tracked over time. To compensate for these problems, records which are not updated or which exhibit excessive employment change are excluded from longitudinal analysis. Records for imputed proxy branches, those with estimated employment figures, and those which indicate they are new coverage of existing businesses are also excluded.

The remaining establishment records with measurable growth are considered a nonrandom sample (about 60 to 70 percent of the original population) whose population distribution is compared to that of the cross-sectional files in the beginning and ending years of the analysis. Accepting the cross-sectional USEEM file as representative of the universe of U.S. businesses with employees, weighting factors are developed as a function of industry division (one-digit SIC), organizational status, establishment employment size, and enterprise employment size. The formulae used to calculate the weighting factors explicitly consider the problems of reporting lags related to formations and failures, and of expanding coverage. During longitudinal processing of the data, a weight is applied to each record in the more reliable sample, bringing their aggregate employment up to the totals in the cross-sectional data.[14] It is this weighted subset of the USEEM which is the basis for longitudinal analysis.

Condensed Longitudinal Data Base

As discussed above, the USEEM comprise an extremely large data set containing millions of records for individual business establishments. Processing the entire set of files is exceedingly expensive and time consuming; therefore, an extract of the data for both 1976 and 1980 was drawn from the USEEM to facilitate manipulation of the data for this analysis. Containing only the sample of records with measurable growth, the records in this extract were restricted to include a subset of the variables from each establishment's USEEM record, an appropriate weight, the location of the establishment (county or SMSA) and the location of the establishment's owner (State). The numeric representation of the SMSA location of the establishment was derived from the USEEM for the county and State, with reference to the Bureau of Economic Analysis' definitions of the SMSAs in the United States for 1980. The State location of the owner was drawn from an auxiliary file containing information for multiestablishment firms. It was constructed from the original DUNS Market Identifier data. The resulting data base is ordered by four-digit SIC codes, allowing efficient analysis at any level of industry aggregation.

Metropolitan and Regional Growth Tables

Descriptive tables were developed to provide aggregate data on employment and employment change for the various industrial sectors under examination and for 35 selected SMSAs (see table B-1). Summary tables are also provided for the four major geographic regions of the United States and for the national totals. These tabulations are valuable sources of summary information on the distribution of business establishments and employment and on changes in these measures between 1976 and 1980. Classified by several dimensions reflecting the characteristics of the individual establishments in each geographic area, these tables provide a rich source of descriptive information in themselves, as well as input data for the regression analyses described later in this paper. The characteristics used for classifying establishments for aggregation are given in table B-2.

Metropolitan Area Aggregate Data Base

The USEEM along with auxiliary variables for 35 SMSAs were used in regression analyses to empirically determine those factors most important in explaining the growth of high-technology establishments. The general rule used in the selection of these 35 SMSAs required that a wide range of values for each of the auxiliary variables be represented in our sample. For example, metropolitan areas at both the high and low ends of the average wage scale were selected. Also, SMSAs of differ-

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[13] For any cross-sectional file, these proxy branch establishments represent approximately 9 percent of all establishments and contain about 22 percent of total employment.

[14] This weighting scheme assumes the use of large samples. Studies focused on narrowly defined populations should bear this in mind. For an extensive discussion of the weighting techniques see C. Armington and M. Odle, "Weighting the USEEM Files for Longitudinal Analysis of Employment Growth," Working Paper No. 12, Business Microdata Project, The Brookings Institution, April 1983.

Table B-1.—1976 Employment and 1976-80 Employment Growth for Selected SMSAs Analyzed

			Percent employment growth	
SMSA listing	1976 total employment	High-technology employment	All industries	High-technology industries
Albuquerque, NM	133,949	14,016	41.7	33.4
Anaheim, CA	615,167	102,150	46.5	37.5
Atlanta, GA	899,761	31,362	6.9	32.9
Austin, TX	135,811	7,788	33.5	182.4
Baltimore, MD	710,828	24,377	15.6	63.3
Baton Rouge, LA	139,616	7,094	41.3	48.9
Boise City, ID	43,203	679	33.2	135.3
Boston, MA-NH	1,682,753	208,388	10.5	26.9
Buffalo, NY	513,174	28,815	2.9	18.5
Chicago, IL	3,439,570	336,837	2.9	−5.6
Cincinnati, OH-KY-IN	584,522	41,371	9.3	15.6
Denver-Boulder, CO	682,577	41,522	34.7	64.4
Detroit, MI	1,499,361	73,297	6.9	15.7
Houston, TX	1,358,504	126,131	18.9	47.6
Kansas City, KA-MO	545,141	37,807	27.2	5.6
Louisville, KY	380,616	21,664	39.2	−5.8
Miami, FL	702,456	15,222	5.0	38.2
Milwaukee, WI	629,013	70,446	8.3	4.3
Minneapolis-St. Paul, MN-WI	871,042	84,489	15.5	−5.4
New Haven, CT	280,972	23,518	11.1	22.5
Omaha, NE-IA	253,527	11,345	11.8	10.4
Philadelphia, PA-NJ	1,777,036	215,875	1.4	−27.6
Phoenix, AZ	380,035	38,457	36.5	43.7
Pittsburgh, PA	897,290	44,983	4.7	10.7
Portland, ME	95,660	2,114	26.5	55.0
Portland, OR-WA	446,097	19,214	24.3	18.3
Raleigh-Durham, NC	198,139	17,613	19.5	56.1
Rochester, NY	342,548	73,755	−2.1	−38.3
St. Louis, MO-IL	881,855	69,826	14.9	22.9
Salt Lake City, Ogden, UT	252,392	21,233	44.5	30.4
San Diego, CA	461,782	62,334	25.3	8.9
San Jose, CA	521,405	154,909	23.6	28.7
Seattle, WA	585,397	48,286	41.7	160.1
Tampa-St. Petersburg, FL	432,427	17,729	27.6	72.9
Wilmington, DE-NJ-MD	183,634	31,257	1.4	−1.4

SOURCE: Office of Technology Assessment

ent population sizes were chosen carefully from each geographic region to ensure each region's fair representation in the sample.

Five of the variables were extracted from the USEEM Condensed Microdata Base. These were base year (1976) employment and establishment counts, end-year employment and counts (1980), and the number of new business formations (1976-80). These four variables were aggregated for each of the four industry groupings: the high-technology with high growth sector, the total high-technology sector, the low-technology manufacturing and business services sector, and the "other industries" sector. Further, each of the four aggregates was compiled for three employment size classes (see table description above). The remaining variables were obtained from a variety of sources of data on SMSAs, as described below. Transformation of these USEEM aggregates led to the following additional variables for the regression analyses: overall employment growth for 1976-80 for each SMSA, the high-technology sector's share of this employment, the low-technology share of employment, and the other industry share of employment.

The data for the variables describing socioeconomic characteristics of the metropolitan areas were drawn from several sources including published data from the Census Bureau, published data on wages and the labor force from the Bureau of Labor Statistics (BLS), and a recent study published by the Advisory Commission on Intergovernmental Relations on local taxes by metropolitan area. Table B-3 details the measure and source of each variable in the data base.

High Technology: Definition and Description

"High technology" has become a phrase frequently used and ambiguously applied in both the professional and popular literature. The term's possible interpretations range from a small grouping of "new age," research-intensive industries with sophisticated new products, such as computer hardware and software, to a broader set of industries, including all manufacturing activities which are implementing new methods or machinery. Even the academic literature evidences little consistency or rigor in defining "high-technology" industries. Obviously, establishing criteria for systematically identifying those industries to be included in the "high-technology" genre is a prerequisite to studying their characteristics and growth patterns.

In order to assess the broad impact of high technology on business formation and growth, some precision must be sacrificed in its definition. At best, businesses can be classified by the four-digit SIC code indicating their predominant industrial activity. Significant aggregation problems arise from three sources: 1) within a given class of industrial activity there are products and processes which are not in an innovative phase, 2) particular firms engage in activities outside the primary industrial activity by which they are classified, and 3) the period of high growth associated with a specific innovation may last much less than a year or may continue, fueled by related innovations, for many years.

Any analytic technique which attempts to categorize industries into "high technology" and "low technology" is bound to be flawed. All operational definitions currently in use employ data that are at least ordinal in nature and often continuous. Schemes to reduce such information to a nominal categorization, such as "high"

Table B-2.—USEEM Establishment Characteristics

A. Organizational status:
1. Independents—single-establishment firms
2. Tops—owners of multiestablishment firms
3. Local affiliates—branches or subsidiaries whose owning firm is located in in the same State
4. National affiliates—branches or subsidiaries whose owning firm is not located in the same State

B. Firm (enterprise) employment size:
1. Tiny establishments—in firms with fewer than 20 employees
2. Mid-small establishments—in firms with 20 to 99 employees
3. Large establishments—in firms with 100 or more employees

C. Primary industrial activity:
1. High technology (see definition below)
2. Other manufacturing and business services
3. All other industries—i.e., not in 1 or 2

D. Type of longitudinal change:
1. Formation—initial startup of a new establishment
2. Closing—cessation of operations of existing establishment
3. Expansion—continuing establishment with increasing employing
4. Contraction—continuing establishment with decreasing employment
5. Stable—continuing establishment with no employment change

E. Geographic location:
1. SMSA—35 Standard Metropolitan Statistical Areas
2. Region—four regions (Northeast, North Central, South, West)
3. National totals

SOURCE: Office of Technology Assessment

Table B-3.—Metropolitan Variables

Type	Variable	Measure
Sector growth	Sector formation (1)	1976-80 new establishments in sector
	Sector formation rate (1)	1976-80 new establishments in sector/1976 employment
	Sector growth rate (1)	1980 sector employment/1976 sector employment
Strength of economy	Employment growth (1)	1980 SMSA employment/1976 SMSA employment
	Employment rate (3)	1.00 minus 1976 SMSA unemployment rate
Business costs	Electricity costs (2)	Average monthly commercial payments in 1976
	Wage rates (5)	1976 average wage for production workers
	Local tax per capita (4)	ACIR capacity index/effort index
City characteristics	Population (2)	1975 SMSA population
	Population density (2)	1975 SMSA population per square mile
	Percent manufacture (2)	1975 manufacturing employment/SMSA employment
	Population growth (2)	1975 population/1970 population
Sector strength	Sector size (1)	1976 sector employment
	Sector share (1)	1976 sector employment/1976 SMSA sector employment
Labor quality	Percent college (2)	1975 population with 4 years of college/adult population
	Percent technical (2)	1975 scientific, professional and technical employees/ total employed labor force

SOURCES:
1. USEEM, Business Microdata Project, The Brookings Institution, 1983.
2. Bureau of the Census, *City and County Data Book: 1977*, 1980.
3. Bureau of the Census, *Metropolitan Area Data Book: 1982*, 1983.
4. Advisory Commission on Intergovernmental Relations, "Interstate Tax Computation," draft 1983.
5. Bureau of Labor Statistics, *Employment and Earnings*, fall 1977.

and "low," are essentially arbitrary.[15] Most serious is the problem of aggregation in industry classifications mentioned above. Since each business establishment can produce numerous products and services, there is possible pollution of its primary industrial classification due to secondary products and activities. Furthermore, alternative production processes can span the range of available technologies associated with a particular product or service, producing at best an agglomeration of somewhat heterogeneous operations within a given industry grouping.

Criteria for Selecting High-Technology Industries

Bearing in mind these deficiencies inherent to the task, previous efforts to identify those industries which can most clearly be identified as high technology were reviewed. An examination of the existing literature revealed two relatively rigorous approaches to defining "high technology" based on available statistics. One approach draws upon data on the occupational composition of industry classes as described by the BLS industry-occupation matrix constructed for the standard industrial classifications (three-digit SIC) from the Occupational Employment Survey. The other utilizes information on expenditures for R&D activities collected and published by NSF.

Researchers at Northeastern University, using the industry-occupation matrix from the 1980 Occupational Employment Survey, defined as high technology those industries with more than 8 percent of their employees in scientific, engineering, and technical occupations and at least 5 percent in the more narrow class of scientific and engineering occupations.[16] These breakpoints were determined by the average proportion of such high-technology jobs in durable goods manufacturing, which employs the largest number and highest proportion of high-technology workers of the major industrial groups in the economy. The resulting list of 32 industries (three-digit SIC) encompasses several service, transportation and communication, and mining industries, as well as manufacturing industries. Utilization of this labor content criteria focuses the analysis on the technology embodied in the production process, rather than the characteristics of the material inputs or products.

The second approach to defining high technology has relied on information on the expenditures for applied R&D for particular product lines relative to some measure of their worth—e.g. value-added or value of shipments. Most analyses using this measure have limited their consideration to direct technology inputs of the final producer, excluding the technological composition of intermediate inputs. To circumvent the limitations of measures of direct R&D, Lester Davis developed an index ranking industries on the basis of both direct and indirect R&D expenditures as a portion of product sales for the manufacturing product classes for which NSF collects detailed R&D data.[17] Estimates for the indirect R&D input and the resultant total R&D for each product field were generated by an input-output matrix for the U.S. manufacturing sector. The use of total R&D, rather than just direct, significantly changed the rankings of the 32 NSF product classes. To determine a breakpoint above which product classes would be considered high technology, Davis assumed that there should be a discernible point of discontinuity indicating substantially greater technological in tensity in the next higher rank. Such a break was present in a 30-percent jump between the motor vehicle equipment class and the plastic materials and synthetic resins class. Thus, Davis identified a total of 10 NSF product classes, representing 18 three-digit SIC classes, as high-technology industries.

Fourteen of Davis' 18 industries are also in the Northeastern University's listing of 20 manufacturing industries. However, the additional six in the Northeastern list based on occupational composition represent almost 29 percent of Northeastern's total high-technology employment. Four of Davis' industries were missing from the Northeastern list. These two groups are presented below:

Low R&D, high-technology occupation	*High R&D, low-technology occupation*
Industrial organic chemicals	Radio and TV receiving equipment
Miscellaneous chemical products	Surgical, medical and dental equipment
Petroleum refining	Ophthalmic goods
Construction machinery	Watches and clocks
General industrial machinery	
Electrical industrial apparatus	

Accepting the necessarily arbitrary nature of defining high-technology industries, the definition based on occupational composition was adopted, but supplemented with the four additional categories with high R&D expenditures, but lower proportions of scientific and technical personnel than the established cutoff. The resulting definition is more comprehensive, covering several nonmanufacturing industries whose products (and services) are technologically intensive and whose potential contribution to employment is significant. Some further modifications were made to the list of high-technology industries produced by these criteria. The manufacturing and business services sectors contain most of the industries passing the high-technology criteria. A few high-technology components of the transportation and communication sector were excluded because much of their industrial group dynamics between 1976 and 1980 was influenced by Federal and local regulation and deregulation. The petroleum extraction industry from the mining sector was retained due to ambiguities in the assignment of firms between this and the petroleum refining industry in manufacturing.[18]

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[15] For a discussion of the imprecision afflicting definitions of high technology, see Donald Tomaskovic-Devey and S. M. Miller, "Can High-Tech Provide the Jobs?" *Challenge*, May-June 1983; *Encouraging High-Technology Development* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-BP-STI-25, March 1984); and Amy Glasmeier, Ann Markusen, and Peter Hall, "Defining High Technology Industries," Working Note No. 1, Institute of Urban and Regional Development, University of California, March 1983.

[16] Richard Greene, Paul Harrington, and Robert Vinson, "High Technology Industry: Identifying and Tracking Emerging Sources of Employment Strength," *New England Journal of Employment and Training*, fall 1983.

[17] Lester Davis, "New Definition of 'High Tech' Reveals That U.S. Competitiveness in This Area Has Been Declining," *Business America*, Oct. 18, 1982.

The data set used in this analysis provides detailed industrial classifications, so all the high-technology industries identified at the three-digit level with the Northeastern University's criteria were expanded into their four-digit SIC components. This procedure made the problem of aggregation in industry classifications more obvious. While few would argue the high-technology status of an industry like SIC 348: Ordinance and Accessories, one of its components is SIC 3482: Small Arms Ammunition, which is not really within the concept of high technology. In order to respect the rigorous definition, no four-digit manufacturing industries were eliminated from the list, so it remains comparable to most based on three-digit classifications. However, the business services classifications comprised such a heterogeneous set of industries with such a large number of employees that it was determined necessary to further modify the definition.

Exploratory tabulations indicated that those business service industries which one would intuitively classify as high technology accounted for only 10 percent of the employment in the aggregated set of business service industries identified with the occupational composition criterion. By sheer volume, the other industries with 90 percent of the employees would have dominated the behavior of the entire aggregate high-technology sector. Retaining all the four-digit business service industries included in the three-digit classes identified with the occupational composition criterion would seriously distort the aggregate data. Therefore, eight four-digit business service industries were eliminated. Two of these eight encompass a highly diversified set of miscellaneous services—"business services, not elsewhere classified" and "services, not elsewhere classified." Two others employ large proportions of engineering and professional personnel, but rely primarily on established techniques—engineering and architectural services and general management consulting. The remaining four provide narrowly defined services, which in themselves do not embody evolving technologies—detective agencies, equipment leasing, photofinishing labs, and trading stamp services. The final list of the 88 four-digit industrial classes included as high-technology industries for this study, as well as the qualifying industries that were excluded, are listed in table B-4 along with their 1976 employment and 1976-80 growth rates.

High-Technology Industries in Perspective

Describing the high-technology sector and assessing its potential contribution to regional development requires a perspective on its economic role relative to other industrial sectors. In this study, two different broad classes of industries are used as bases for examination of the relative importance and growth performance of high-technology industries. Since the definition of "high technology" has been confined primarily to manufacturing and business services, excluded industries belonging to these industry groups provide the best basis for comparison, henceforth termed "low-technology manufacturing and business services" or "low-technology industries." The other reference population comprises all nongovernmental industries not classified in manufacturing and business services, termed "other industries." Attempts are made to be as explicit as possible in referring to the appropriate base population, while avoiding tedious repetition. Having now defined the industry sectors of interest, let us examine their characteristics and distribution in the economy.

Less than 2 percent of the business establishments in the United States in 1976 fell under the heading "high technology." Employment in high-technology establishments in 1976 was 5.6 million, or 7.4 percent of the private sector total.[19] One-fifth of all employment in manufacturing and business services in 1976 was in high technology. The attention received by the high-technology sector is merited by its potential for growth, not by its current employment size. The high-technology sector's share of value-added is somewhat larger than its share of manufacturing employment.[20]

The organizational composition of the high-technology sector differs importantly from the rest of the business population. Several aspects of this difference are apparent in table B-5. Although 60 percent of all U.S. private sector jobs are in multiestablishment firms, the high-tech-

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[18] The classification problem afflicting this industry is manifested in all Federal and private data sources.

[19] While excluding those establishments explicitly classified as "government," the USEEM base (and therefore the total employment figures) does include many other public sector establishments, such as State universities and health service establishments.

[20] In a study, Robert Lawrence estimated that in 1980 high technology accounted for 33 percent of manufacturing employment and 38 percent of total value added. See Robert Lawrence, "Is Trade Deindustrializing America?" in *Brookings Papers on Economic Activity, 1:83,* G. Perry and G. Burtless (eds.) (Washington, DC: The Brookings Institution, 1983).

Table B-4.—High-Technology Industries

Industries		1976 national employment	1976-80 national growth rates
1311	Crude petroleum and natural gas	289,618	−5.7
1321	Natural gas liquids	6,018	8.8
2812	Alkalies and chlorine	27,974	−19.0
2813	Industrial gases	21,800	7.9
2816	Inorganic pigments	28,405	2.9
2821	Plastic materials, synthetic resins, and nonvulcanizable elastomers	144,346	12.4
2822	Synthetic rubber	23,453	26.8
2823	Cellulosic manmade fibers	33,376	−35.3
2824	Synthetic organic fibers	69,843	−4.1
2831	Biological products	14,828	−0.5
2833	Medicinal chemicals and botanical products	27,735	10.2
2834	Pharmaceutical preparations	184,195	8.5
2861	Gum and wood chemicals	10,853	13.1
2865	Coal tar, crudes and cyclic intermediates, dyes and organic pigments	16,285	3.7
2891	Adhesives and sealants	23,916	−2.6
2892	Explosives	24,998	−24.8
2893	Printing ink	14,080	14.2
2895	Carbon black	9,813	−62.4
2899	Chemicals and chemical preparation, n.e.c.	64,841	10.2
2911	Petroleum refining	128,751	39.5
3482	Small arms ammunition	12,870	−0.6
3483	Ammunition	29,760	13.7
3486	Small arms	24,569	−16.2
3489	Ordinance and accessories	6,018	−0.8
3511	Steam, gas, hydraulic turbines	76,777	32.9
3519	Internal combustion engines	90,639	13.8
3531	Construction machinery and equipment	159,515	19.2
3532	Mining machinery	30,663	24.3
3533	Oil machinery	81,165	27.5
3534	Elevators and moving stairways	20,634	−6.0
3535	Conveyors	36,020	24.7
3536	Hoists, industrial cranes	24,308	17.8
3537	Industrial trucks, tractors, trailers, stackers	45,043	19.4
3561	Pumps and pumping equipment	65,685	48.3
3562	Ball and roller bearings	63,513	20.3
3563	Air and gas compressors	18,157	23.0
3564	Blowers and exhaust and ventilation fans	44,669	10.5
3565	Industrial patterns	12,321	2.7
3566	Speed changers, industrial high-speed gears	55,840	1.8
3567	Industrial process furnace and ovens	26,065	19.9
3568	Mechanical power transmission equipment	9,555	25.6
3569	General industrial machinery	76,552	20.8
3572	Typewriters	18,378	−2.1
3573	Electronic computing equipment	274,699	16.5
3574	Calculating and accounting machines	17,234	8.4
3576	Scales and balances	9,731	13.0
3579	Office machines	33,768	17.0
3622	Industrial controls	87,561	26.3
3623	Welding apparatus	21,335	25.4
3624	Carbon and graphite products	14,887	17.1
3629	Electrical industrial apparatus	33,199	11.4
3651	Radio and TV receivers	115,758	−17.3
3652	Phonograph records and tapes	26,794	21.7
3661	Telephone and telegraph apparatus	164,983	2.5
3662	Radio-TV transmitting	339,865	15.7
3671	Radio and TV electron tubes	12,120	−10.9
3672	Cathode ray TV picture tubes	13,279	−8.1
3673	Transmitting, industrial electron tubes	19,158	2.0
3674	Semiconductors	153,123	28.2
3675	Electronic capacitors	21,380	−55.2
3676	Resistors for electronic apparatus	4,698	57.4
3677	Electronic coils, transformers	8,153	28.5
3678	Connectors for electronics	4,415	74.5
3679	Electronic components, n.e.c.	262,215	33.0
3721	Aircraft	243,436	35.3
3724	Aircraft engines and engine parts	71,504	41.2
3728	Aircraft parts and equipment, n.e.c.	118,586	19.0
3761	Guided missiles and space vehicles	61,043	24.7
3764	Guided missiles and space propulsion units	10,043	−76.4
3769	Guided missiles and space parts and equipment, n.e.c.	645	75.7
3811	Engineering, lab, science research instruments	69,962	25.4
3822	Automatic controls for regulating residential and commercial environment	69,806	8.0
3823	Industrial instruments for measuring and control of process variables	45,850	43.8
3824	Totalizing fluid meters and counting devices	15,011	−9.4
3829	Measuring and controlling devices	17,384	27.3
3832	Optical instruments and lenses	23,909	23.5
3841	Surgical and medical instruments	47,023	67.6
3842	Orthopedic and surgical supplies	60,426	22.8
3843	Dental equipment	19,120	17.6
3851	Ophthalmic goods	36,915	30.6
3861	Photographic equipment	103,480	−19.8
3873	Watches, clocks	34,235	11.8
Business services			
7372	Computer programming and other services	65,870	98.9

Table B-4.—High-Technology Industries (continued)

Industries	1976 national employment	1976-80 national growth rates
7374 Data processing equipment	162,753	54.4
7379 Computer related service, n.e.c.	43,433	47.5
7391 Research and development labs	314,988	20.6
7397 Commercial testing labs	61,513	35.9
8922 Noncommercial educational and science research organizations	90,161	85.9
Total high technology	5,619,295	19.4
Qualifying industries excluded from the high-technology sample		
7392 Management consultant, public relations	611,697	45.7
7393 Detective and protection services	299,226	25.0
7394 Equipment rental and leasing	204,469	32.8
7395 Photofinishing laboratories	84,092	18.3
7396 Trading stamp services	6,230	−13.6
7399 Business services, n.e.c.	595,488	36.8
8911 Engineering, architectural, and survey services	707,753	34.4
8999 Services, n.e.c.	104,183	45.4

SOURCE: Office of Technology Assessment

Table B-5.—1976 Shares of High-Technology Establishments and Employment by Affiliation and Firm Size (percent)

	Multiestablishment firms		Large firms[a]		Tiny firms[b]	
	Establishment	Employment	Establishment	Employment	Establishment	Employment
High technology	43.8	88.4	29.5	89.0	53.4	4.2
Low technology	28.9	72.7	16.9	75.0	66.9	10.6
Other industries	25.3	51.1	9.7	57.7	80.5	25.3
All industries	26.2	60.0	12.4	64.0	76.0	20.0

[a] Large firms have 100 or more employees firmwide; most are multiestablishment.

[b] Tiny firms have less than 20 employees firmwide; most are independents.

SOURCE: Office of Technology Assessment.

nology sector is even more dominated by such firms (88 percent of jobs). About one-half of all high-technology jobs are in national affiliates (branches and subsidiaries of firms headquartered out-of-State), while the average for all industries is only one-third.

The average number of employees in high-technology establishments (69) is twice that of the low-technology manufacturing and business services (32) and more than five times the average in other industries (13). Almost 90 percent of high-technology jobs are in firms with more than 100 employees compared to 75 percent for low-technology and 58 percent for all other industries. The high-technology sector comprises 1.6 percent of all tiny firm employment, 3.2 percent of mid-small firm employment, and 10 percent of large firm employment.

While the distribution of high-technology employment across the four regions of the United States roughly parallels the distribution of overall employment, the regional share data in table B-6 show that the Northeast and the West have more than their proportional share of high-technology employment, while the South is short. This is more clearly evident in the variation in the sectoral shares within each region. The employment share of the high-technology sector varies from 5.8 percent in the South to 8.9 percent of all jobs in the Northeast. The West has a high-technology sector which is somewhat above average, but it is considerably below average in the size of its low-technology manufacturing and business services sector.

There is remarkable variation across regions in the organizational composition of the high-technology sector, particularly with respect to multiestablishment firms, which is shown in table B-7. Employment in high-technology affiliate establishments in the South exhibits the

Table B-6.—Distribution of Total Private Sector Employment by Region and Industrial Sector, 1976 (percent)

Region	Sector within region		Regional share	
	High-technology	Low-technology	High-technology	All industries
Northeast	8.9	30.6	29.3	24.8
North Central	7.4	30.8	27.6	27.6
South	5.8	27.3	23.8	30.6
West	8.4	22.3	19.3	17.0
U.S. total	7.4	28.2	100.0	100.0

SOURCE: Office of Technology Assessment.

Table B-7.—Distribution of High-Technology Employment by Organizational Type, 1976 (percent)

Region	Independents	Tops	Local affiliates	National affiliates
Northeast	12.9	21.1	22.3	43.7
North Central	10.4	24.7	17.4	47.4
South	10.1	12.9	9.4	67.6
West	13.0	16.0	21.7	49.3
U.S. total	11.6	19.2	17.8	51.5

SOURCE: Office of Technology Assessment.

greatest divergence from the mean. Whereas less than 50 percent of high-technology employment in the other regions is in national affiliates, in the South out-of-State headquarters control about 68 percent of all high-technology jobs. Though less exaggerated, affiliate employment in other industrial sectors in the South has a similar trend.

Regional Aspects of High-Technology Development

Overview

Recent recession and record unemployment levels have prompted policymakers to look increasingly toward the fast-growing high-technology sector of the economy as an important source of new jobs. In view of the remarkable growth in some, especially computer-related industries, many local planning and development agencies are directing their resources toward attracting these industries to their areas. Yet very little is known at present about the plant location decisions of high-technology firms or even about the characteristics of growth in high-technology industries. In the previous section the high-technology sector and its distribution by region and organizational status in 1976 was described. This section focuses on the locus of growth in the high-technology sector between 1976 and 1980.

Did the patterns of employment growth between 1976 and 1980 erode or reinforce the existing distribution and composition of employment in the high-technology sector? Employment in high-technology industries in the United States grew a total of 19.4 percent between 1976 and 1980, an average annual growth rate of 4.5 percent. The growth of employment in high-technology industries was a third higher than the employment growth in the low-technology part of the manufacturing and business services. Consequently, the high-technology sector increased its 21-percent share of the manufacturing and business sector service employment to 22 percent by 1980. Within the high-technology sector, the subset of high-growth industries grew from 65 percent of all high-technology employment to 71 percent due to their average growth rate of 31 percent. Over this same period, the low-technology manufacturing and business services sector grew almost 12 percent, while the "other industries" sector grew 16 percent.

High-technology industries contributed 9.5 percent of all net new jobs between 1976 and 1980, of which 72.4 percent were in large businesses. The low-technology sector's share of net new jobs created between 1976 and 1980 was 21.7 percent; "other industries" was 68.8 percent. This growth in the low-technology manufacturing and business services industries raises doubts concerning recent claims that traditional basic manufacturing industries are dying out in the United States.

As shown in table B-8, the two regions with the lowest shares of high-technology employment in 1976 experienced the highest rates of growth during the 1976-80 period. Although they held only 43 percent of total employment in high technology in 1976, the South and the West together accounted for 71 percent of that sector's

Table B-8.—Employment Growth Shares and Growth Rates by Region and by Sector, 1976-80 (percent)

	High technology			All industries		
Region	Share of employment	Share of growth	Growth rate	Share of employment	Share of growth	Growth rate
Northeast	29.3	11.3	7.5	24.8	10.4	6.4
North Central	27.6	17.8	12.5	27.6	21.6	11.9
South	23.8	41.8	34.1	30.6	38.1	18.9
West	19.3	29.1	29.3	17.0	29.9	26.7
U.S. total	100.0	100.0	19.4	100.0	100.0	15.2

SOURCE: Office of Technology Assessment

growth between 1976 and 1980. Thus regional shares of high-technology employment are tending to converge, balancing the distribution across the four regions. This regional distribution of growth in high-technology employment roughly paralleled that in low-technology manufacturing and business services.[21]

The Northeast and the West had relatively strong high-technology sectors reflected in the larger shares of high-technology employment relative to overall employment. The North Central had proportional shares of national employment in both sectors, while the South had a relatively small high-technology sector. Given the noted tendency toward a more balanced distribution of high-technology employment, it is not surprising that the greatest excess in high-technology growth rate relative to the region's overall growth rate was in the South (34 percent v. 19 percent). Obviously, the regions used in this analysis are very broadly defined, and the high-technology employment within those regions may be highly concentrated in particular States or metropolitan areas. Regional analysis at a more disaggregated level would illuminate such intraregional discrepancies.[22]

Analysis of Regional Shifts in Employment Shares

Employment growth in the high-technology industries for a given area comes from a variety of sources. Regional employment growth may result from a number of factors, in addition to simply reflecting national economic trends. Particular regional characteristics might be attractive to businesses in general, regardless of their level of technology or innovativeness. Such factors would include abundant and inexpensive energy or labor resources. Other regional characteristics might be of particular relevance to high-technology firms, such as a large pool of technical and scientific workers. Third, growth in a region's high-technology sector could result from expansion within existing high-technology firms or the formation of new high-technology establishments resulting from a nationwide increased demand for their products.

What is the relative impact on regional employment growth of their competitive advantages versus that of their particular industrial structures? Shift share analysis is a useful technique for addressing this question.[23] This analysis divides growth of a region into a national component (the national average growth rate), an industrial mix component (expected deviations from the national average attributable to the composition of the regional economy in terms of fast- and slow-growing industries), and a regional competitive component (differences in regional growth rates compared to national growth rates for particular industry groups). This technique assumes homogeneity within regions and within industry groups, to the level of aggregation used. Obviously industrial groupings are not homogeneous, as discussed earlier with respect to the problem of defining high-technology industries.[24] However, the areas comprising our regions and the four-digit industry classes grouped in two of our three industrial categories were chosen for their internal consistency in growth rates, so the technique should still be useful at this crude level of aggregation.[25]

The first four columns of table B-9 summarize the findings of a more disaggregated shift share analysis of em-

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[21] Another more detailed regional analysis for the period 1967-78 found a similar tendency toward convergence in regional shares of manufacturing employment. See Gregory Jackson, et al., *Regional Diversity: Growth in the U.S., 1960-1990* (Boston: Auburn Publishing House, 1981).

[22] See, for example, Andrew Wyckoff and Nancy O'Connor, "Patterns of Growth and Structural Change in High Technology Industries in the New England States," Business Microdata Project, The Brookings Institution, August 1983, (mimeo).

[23] For a discussion of shift share analysis see Jackson, et al., op. cit.; or L. D. Ashby, *Growth Patterns in Employment by County, 1940-50 and 1950-60* (Washington, DC: U.S. Government Printing Office, 1965).

[24] This is true of broad classes such as the three employed here: high-technology/high-growth, high-technology/low-growth, and low-technology manufacturing and business services. See M. Odle, "High Technology versus High Growth Industries," Small Business Research Conference Papers (Waltham, MA: Bentley College, 1983).

[25] The annual percentage change in nonagricultural employment between 1970 and 1977 for the divisions comprising our four regions are given below:

Northeast		South	
New England	0.90	South Atlantic	2.87
Mid-Atlantic	0.15	East South Central	3.13
North Central		West South Central	4.26
East North Central	1.22	West	
West North Central	2.23	Mountain	5.26
		Pacific	3.00

SOURCE: Adapted from table 4.1 in Jackson, et al., op cit.

Table B-9.—Shift Share Analysis of Changes in Manufacturing Employment (estimated effects in thousands of employees)

Region	1963-72[a] Competitive	1963-72[a] Mix	1972-76[a] Competitive	1972-76[a] Mix	1976-80[b] Competitive	1976-80[b] Mix	Total change
Northeast	–954	93	–396	9	–615	2	369
North Central	–178	141	–76	60	–302	–24	744
South	884	–29	502	–78	486	–52	1,457
West	35	–7	158	–5	431	75	1,034

[a] Adapted from John Rees, "Regional Industrial Shifts," table 3

[b] The 1976 base includes manufacturing employees (21.77 million), petroleum extraction employees (0.29 million) and business services employees (4.93 million).

SOURCE: Office of Technology Assessment.

ployment growth in manufacturing for two earlier periods.[26] The relatively slow growth in the traditional manufacturing regions, the Northeast and North Central, in contrast to the faster growth in the newer manufacturing centers in the South and West is apparent in all three time periods shown in table B-8. The traditional manufacturing regions have consistently large negative competitive components. In the most recent period the competitive component of employment loss attributable to the Northeast's weak economy was nearly twice the size of the actual net gain in employment. If the national growth rates for the mix of industry sectors had prevailed in the Northeast—i.e., if the regional competitive effect had been zero, rather than negative—then its employment growth would have been nearly three times as large as it actually experienced.

The competitive regional advantages of the South and the West appear to be in transition. Since the 1963-based analysis, the South's competitive component has been decreasing, while the West's has been increasing. In the most current period the employment gains attributable to differences in their regional economies were nearly the same, although the South is almost twice as large (in employment) as the West.

Trends in the industrial mix effects are more startling. While the Northeast used to have a large enough share of high-growth industries to more than offset its very high share of low-growth manufacturing, the mix is now just barely balanced. This trend of decreasing advantage of industrial mix is even stronger in the North Central region, whose earlier advantageous industrial composition effect was almost large enough to offset its disadvantageous competitive effect. In the recent period, both effects were negative. Both of these regions' negative mix effects are probably understated because the low-technology sector was not disaggregated. These regions would tend to include the older, slower growing industries within that industrial sector.

The South continues to have a relatively small share of the high-growth industries, in spite of its overall economic health. This is a restatement of the point made above, that although the South had by far the highest growth rate for high-technology business, it had the smallest proportion of high-technology business. The West, on the other hand, appears to be the paradigm for every regional development council. In addition to the substantial competitive advantage of its regional economy, the West shows an increasingly favorable industrial mix in the recent period. The industrial structure in the West has shifted, so it has more than its expected share of high-growth industries.

Two general conclusions from the shift share analysis are particularly clear. First, the regional competitive effects overwhelm the industry mix effects in all these periods. Second, in spite of some shining examples of the contrary, the older manufacturing areas are losing their advantageous industrial mix in manufacturing. This might be due to a shift in the locus of innovations and development of new product lines, or it might reflect a change in the pattern of location of branch plants in lower wage areas as high-technology products enter the stage of larger scale, standardized production. Some evidence for the latter effect was found in the organizational composition of high-technology growth, particularly in the South. (See discussion below.)

Composition of High-Technology Employment Growth

Components of Employment Change.—The data used in this analysis allow us to differentiate employment growth behavior for different types of firms within the high-technology sector. These data track individual firms over time, permitting classification of establishments according to the their type of employment growth: formations, expansions, contractions, and closures. The figures in table B-10 show high-technology industries have higher growth rates than low-technology industries in all regions. This was true for both formations and expansions. The greatest contrast in the performance of

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[26] The figures in table B-8 represent the expected change in the region's employment in thousands relative to the national growth rate for all industries and given its particular industrial mix. The last column is the actual net change in employment for the 1976-80 period.

Table B-10.—Employment Change by Type and Region for High- and Low-Technology Manufacturing and Business Services (percent of 1976 employment with region and sector, 1976-80)

	Net	Formations	Expansions	Contractions	Closures
Northeast					
High	7.5	16.3	21.3	–13.7	–16.4
Low	4.3	14.2	18.9	–11.6	–17.2
North Central					
High	12.5	19.6	19.2	–10.4	–15.9
Low	8.5	16.3	18.6	–10.5	–15.8
South					
High	34.1	34.2	27.9	–9.6	–18.5
Low	15.8	22.5	22.3	–10.0	–19.0
West					
High	29.3	28.4	33.5	–10.9	–21.7
Low	25.0	26.8	27.8	–9.6	–20.0
U.S. total					
High	19.4	23.8	24.6	–11.3	–17.8
Low	11.7	19.0	21.0	–10.5	–17.7

SOURCE: Office of Technology Assessment

high- and low-technology sectors was experienced in the South. In that region, the rate of employment change associated with formations in high-technology industries was 50 percent higher than that in low-technology industries. This was the strongest determinant of the exceedingly high net employment growth rate for the high-technology sector in the South.[27] Contraction and closing rates were almost identical for both high- and low-technology industries in every region.

Organizational Aspects of Employment Growth.—High-technology firms can also be classified by organizational structure. As pointed out in the section describing the high-technology sector, most of the employment in these industries is in affiliates of large multiestablishment firms. Data in table B-11 are separated into four types of business establishments based on their affiliations. Independents are establishments that are not legally connected to other business establishments. Tops are the owning establishments in multiestablishment enterprises. An interesting distinction can be made between the two types of affiliated establishments of multiestablishment firms. Local affiliates are branch or subsidiary establishments of firms whose owning company is located in the same State; national affiliates belong to out-of-State owners.[28]

Although employment in independents in high-technology industries grew rapidly (36.9 percent between 1976 and 1980), their share of the high-technology labor force (11.6 percent) was relatively insignificant compared to the share of employment in high-technology affiliates of multiestablishment firms (88.4 percent). Of the employment growth that took place between 1976 and 1980, about 22 percent was in independents, almost twice their share of base year employment in 1976. Regionally, the ratio of independents' growth shares to base employment shares ranged from 1.6 in the South to 3.2 in the Northeast. For the low-technology sector, this ratio for independents hovered around 1.6 in all regions except the Northeast. In that region, independents made a positive contribution to a net loss of employment in the low-technology sector. Despite the predominance of large affiliates in the high-technology sector, independents performed better on average in high-technology industries than in low-technology industries.

Affiliates of multiestablishment firms accounted for 69 percent of employment growth for the period, approximately equal to their share of high-technology employment in 1976. In the Northeast and the North Central regions, high-technology affiliates' shares of employment growth were higher than their shares of 1976 employment. The reverse was true in the South and the West. For each type of establishment, regional growth rates and growth shares were inversely related to the size of the high-technology sector relative to the region's total employment. Thus the overall pattern of convergence in regional shares of high-technology employment is manifested consistently in all types of establishments.

Local v. National Ownership.—In 1976 in the United States, more than 60 percent of affiliated establishments in the high- and low-technology sectors of manufacturing and business services belonged to out-of-State firms. These national affiliates had nearly three times the employment of affiliates of local (instate) firms. The

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[27] These findings are consistent with earlier regional analyses that indicate the growth component most responsible for regional differences in net job growth was formations. See, for example, John Rees, "Regional Industrial Shifts," or David Birch, "Generating New Jobs: Are Government Incentives Effective?" *Commentary* (Washington, DC: Council for Urban Economic Development, July 1979).

[28] This is the organizational status in 1976, except for formations which are classified by their status in 1980.

Table B-11.—Net Employment Growth Rates in High-Technology Establishments by Organizational Type, 1976-80 (percent)

Region	All types	Independents	Tops	Local affiliates	National affiliates
Northeast	8	24	−4	11	6
North Central	13	22	2	30	9
South	34	53	25	32	33
West	29	57	26	43	17
U.S. total	19	37	8	26	18

[a] Reflects organizational status in 1976, except for formations which are classified by status in 1980.

SOURCE: Office of Technology Assessment.

employment growth between 1976 and 1980 diminished these discrepancies. In the low-technology sector, local affiliates grew 20 percent more than the national affiliates during the period. In every region except the South local high-technology affiliates were growing at two to three times the national affiliates' rate. In the South, local and national affiliates grew at roughly equal rates.

Translating the various employment shares (table B-7) and growth rates (table B-11) into shares of net growth, the relative importance of local v. national affiliates in the job-generation process is more clearly evident. In the Northeast, the North Central, and the West, the number of new jobs was approximately evenly split between affiliates of local firms and affiliates of national firms. In the South, however, about 300,000 of the 340,000 new jobs generated in affiliated establishments were in affiliates of out-of-State firms. Much of this new employment in national affiliates was due to formations of new business establishments.[29] Given the importance of formations in determining net growth rates, let us look at this component of employment change in more detail.

Regional Differences in Formations

For the 1976-80 period, a number of important regional trends are evident in the pattern of high-technology formations and their associated new employment. As with net employment change, the rates of formations of new high-technology establishments and their employment contributions are inversely related to regional shares of high technology in the base year. Again, since closing and contraction rates are fairly constant across regions, formation rates account for much of the difference in overall regional performance. Consistently, the Northeast and North Central had formation rates below the U.S. average for all three of these industry groupings, while the South and West had above average rates, both of establishment formations and job creation (see table B-12).

As shown in table B-13, each region's share of formations and associated employment was relatively constant across all sectors, indicating that there was little variation in the average size of new high-technology establishments across regions. Their constancy across industrial sectors also suggests that location decisions of high-technology firms are not significantly different from those of firms in other industries at this broad regional level. As noted above, this distribution tends to offset existing inequalities in the regional shares of total national employment in the high-technology sector.

The intraregional variations in formation rates across industrial sectors were quite similar. In each region, the formation rate for the high-technology sector was about 30 percent higher than that for the "other industries" sector, except in the South where high-technology formations were nearly 50 percent higher. Low-technology formation rates were almost identical to those of the "other industries" sector in the Northeast and the North Central regions, but low-technology formations were stronger than "other industries" in the South and West.

Turning to the impact on employment, in each region the rate of employment growth from formations was approximately the same in the high-technology as in the low-technology sectors (see table B-12). The South exhibited a considerably higher rate of high-technology job creation. However, recall that the South had the smallest high-technology sector (5.8 percent) relative to its total employment and a smaller share of national high-technology employment compared to its share of total national employment.

Organizational Aspects of Formations.—Representing 56 percent of all high-technology establishments in 1976, independent establishments in all regions accounted for an average of 54 percent of formations in the high-technology sector. Their share ranged from 51 percent in the Northeast to 59 percent in the West. The role of independents in the high-technology sector is relatively weak compared to their 70 percent shares of population and formations in the two other industrial sectors. The distinctive position of independents in the high- and low-technology sectors was more striking in forma-

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[29] This probably underrepresents the strength of out-of-State firms because no account has been taken of their acquisition of local affiliates or independent establishments between 1976 and 1980.

Table B-12.—Establishment Formation Rates by Region and Industrial Sector, 1976-80 (percent)

	U.S. total	Northeast	North Central	South	West
Rate of establishment formations:					
All industries	32.2	26.1	28.5	34.9	40.6
High technology	43.4	33.8	37.6	50.3	51.6
Low-technology manufacturing and business services	33.9	25.4	28.7	39.8	43.3
Other industries	31.7	26.0	28.3	33.8	39.8
Rate of employment change in formations:					
All industries	21.9	16.0	19.2	25.3	28.7
High technology	23.8	16.3	19.6	34.2	28.4
Low-technology manufacturing and business services	19.0	14.2	16.3	22.5	26.8
Other industries	22.9	16.9	28.3	25.6	29.3

SOURCE: Office of Technology Assessment.

Table B-13.—Regional Shares of Establishments and Employment: Net Change and Formations by Industrial Sector (percent)

	Northeast		North Central		South		West	
	Establishment	Jobs	Establishment	Jobs	Establishment	Jobs	Establishment	Jobs
High technology:								
Formations	19	20	21	23	34	34	26	23
Net change	14	11	19	18	38	42	28	29
Low technology:								
Formations	20	20	22	26	32	35	26	[illegible]
Net change	6	10	19	22	39	40	36	29
Other industries:								
Formations	19	17	24	24	34	36	23	23
Net change	4	11	17	22	36	37	43	30

SOURCE: Office of Technology Assessment.

tion of new jobs. From their 11.6 percent share of high-technology employment in 1976, independents contributed 11.9 percent of jobs in high-technology formations between 1976 and 1980. The independents' share of employment from formations in high-technology industries was consistently only one-third to one-half of that of their counterparts in the "other industries" sector in all regions.

The complementary shares of national affiliates in high-technology formations was two to three times their shares of employment and establishments in formations in the "other industries" sector. The South's formation rates gave it a 39 percent share of the national affiliate formations, consistent with its 35 percent share of such high-technology establishments in 1976.

Size Class Patterns in Employment Growth and Formations

How did the employment growth and formation behavior compare for different firm size classes in the various industries and regions? Size class distributions of population and employment growth parallel to a large extent the organizational distribution. That is, most employment in affiliates is in large firms (100 or more employees), while most tiny (fewer than 20 employees) firms are independents (compare table B-14 with table B-5.)

The average high-technology establishment (69 employees) is five times the average size in the "other industries" sector (13 employees). In 1976 less than 4 percent of all high-technology jobs were in firms with fewer than 20 employees (tiny firms); another 8 percent were in firms with fewer than 100 employees (mid-small firms) for a total of 12 percent in the smaller two size classes. In contrast, these two size classes comprised 28 percent of employment in the low-technology sector and 42 percent in the "other industries" sector.

Expectedly, tiny firms experienced the highest percentage growth between 1976 and 1980 of the three size classes. This pattern and the generally higher growth rates for the high-technology sector as a whole combined to produce extremely high-growth rates for tiny high-technology firms, ranging from 54 percent in the North Central region to 91 percent in the West. High-technology growth rates for mid-small firms average about half that of tiny firms, while growth rates of large firms were about half that of the mid-small group. The relative mag-

Table B-14.—Employment Growth Rates and Shares by Firm Size and by Industrial Sector, 1976-80 (percent)

	Number of employees in owning firm							
	All	0-19	20-99	100+	All	0-19	20-99	100+
Industry sector	Growth rates				Growth shares			
High technology	19	70	35	16	100	15	12	73
Low technology	12	44	14	7	100	40	17	43
Other industries	16	23	15	14	100	37	16	47

SOURCE: Office of Technology Assessment.

nitude of growth rates in mid-small firms compared to large firms in the other sectors did not exhibit a similar pattern.

The highly concentrated organizational composition of the high-technology industries was reflected in the distribution of net employment growth. Although the smallest firms contributed only 15.2 percent of net employment change in high-technology industries, this was about four times their share of 1976 employment in that sector. More than 72 percent of the new high-technology jobs were in firms with 100 or more employees. This sharply contrasts with the structure of employment and growth in the other sectors, in which tiny firms contributed close to 40 percent of growth and large firms less than 50 percent. Consistent with their dominant position in the high-technology sector (89 percent of all high-technology employees), large firms accounted for 86 percent of the employment in high-technology formations. In the low-technology sector, large firms contributed only 65 percent of formation employment, considerably less than their 75 percent share of that industrial sector's employment. The share of high-technology formation employment was about 7.5 percent for tiny establishments, whose share of 1976 employment was only 4 percent. In low-technology industries, tiny firms contributed almost twice as many jobs as would have been expected from their share of 1976 employment.

A general pattern of a 20- to 30-percentage point spread between the formation rates in the high- and low-technology sectors holds in each region for both the smallest and largest size classes. The mid-small class (establishments in firms with 20 to 99 employees), showed little variation in regional formation rates between the two industry sectors. While the establishment formation rates are similar for tiny and large firms, the rate of employment increase in formations in the smallest size class ranges from 50 to 80 percent higher than in the largest size class across regions. This differential in growth rates largely reflects the small size of the tiny firms' employment base in 1976. The employment increases of the mid-small class compare more closely with those of the largest class, generally about one-half the rates of the smallest size class.

Summary

The high-technology industries comprise a small, relatively concentrated sector of the economy. Their 7.4 percent share of the Nation's private sector employment is based in large affiliates of large multiestablishment firms. Only 11 percent of high-technology employment is in firms with fewer than 100 employees. The distribution of these jobs across the four broadly defined geographic regions of the United States fits the same general pattern as that of employment in all industries.

Employment in the high-technology sector grew 19.4 percent between 1976 and 1980, about 66 percent faster than the low-technology manufacturing and business services sector. The regions which experienced the highest rates of growth were those which previously had the smallest shares of high-technology employment. Although the South and the West held only 43 percent of the total employment in high technology in 1976, these two regions accounted for 70 percent of that sector's growth between 1976 and 1980.

Since rates of job loss from closings and contractions were similar across regions, net employment growth performance is largely a function of formation and expansion rates. Similar to net employment growth, the formation rates for the high-technology sector are consistently about 30 to 50 percent higher than those for the "other industries" sector. The Northeast and North Central had formation rates below the U.S. average for all three of these industry groupings while the South and West had above average rates of both business and job creation. These distributions of net growth and formations in high-technology employment roughly paralleled those in all industries, indicating a general trend towards equalizing the distribution of both high-technology and other business activity across regions of the United States.

The shift share analysis of manufacturing employment changes in four geographic regions confirmed the trends apparent in the tabular data.[30] In the analysis of data for the 1976-80 period and in the findings of another study for two earlier periods (1963-72 and 1972-76), the most important observation is that the competitive effects of regional employment growth performance overwhelm the mix effects of regional industrial composition. In all three periods competitive effects were negative for the northern regions and positive for the South and West, reflecting a general shift of new economic activity to these more recently developed areas. Furthermore, while the northern regions are losing their previous advantageous mix of manufacturing industries, the West is increasing its proportion of higher growth manufacturing industries.

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[30] The three industrial sectors included low-technology manufacturing and business services and the high-technology sector, which was divided into "low-growth rate" and "high-growth rate" subsectors for this part of the analysis.

Employment in the high-technology sector is predominantly in large establishments of large businesses. Nevertheless, the relative performance of small independent firms compared to larger affiliates was much better in the high-technology sector than in the other sectors. Despite this very strong performance of small and independent high-technology firms, their small share of high-technology employment prevents their making major inroads into the dominant position of the larger firms. Consequently, the organizational and size distributions of the high-technology sector in 1980 remained very much like existing structure of the high-technology sector in 1976.

High Technology in Metropolitan Areas

What regional or metropolitan characteristics foster the formation and continued growth of high-technology businesses? Business formations and employment growth were analyzed for a sample of 35 metropolitan areas to identify characteristics associated with high-technology development. The "low-technology" and "other industries" sectors were also studied in comparison to the high-technology sector to identify any unique characteristics in its growth behavior. Finally, differences in the patterns of formation and growth of very small high-technology businesses compared to high-technology affiliates of large firms were also examined.

Many economic and demographic factors contribute to differences in growth rates. A set of factors was chosen which would adequately explain a large portion of the variation in growth across metropolitan areas. Factors which might be significant for one industry, but not for the majority of industries sector level.

Decisions regarding the location of new business establishments are probably based on different criteria than those determining expansion, contraction, or closings of existing establishments, which together determine net employment growth. Though associated with many of the same factors as formation choices, decisions regarding existing facilities reflect location decisions of earlier periods, current fluctuations in economic conditions, and the dynamics of particular firms and industries. In view of this, separate equations were formulated using as the dependent variable either: 1) the rates of formation of new business establishments, or 2) the rates of net employment growth, for the period 1976-80.[31] Nonetheless, business formations constitute an important, if not determinant, force in net employment growth which should render the relationships qualitatively similar, but perhaps quantitatively weaker for the net growth rates.

The relationship of the dependent variables to the metropolitan characteristics was also expected to vary across industrial sectors, so the two equations were estimated separately for each of the three industrial sectors: high-technology industries, "low-technology" (other manufacturing and business service) industries, and "other industries." The subset of high-technology industries which had above average growth was also analyzed separately. However, the results were so similar to those for the whole high-technology sector that they are not explicitly presented in this appendix.

Variables and Their Relationships to High-Technology Development

It was hypothesized that each of the dependent variables would be related multiplicatively to some or all of the following factors:[32]

- the pool of potential entrepreneurs,
- the relative costs of doing business,
- the level of activity in that industrial sector,
- regional economic conditions,
- the quality of the labor force, and/or
- general attractiveness of the city.

What were the expected relationships between these factors and the measures of growth and how were they operationalized?

In general, business formations should have a strong positive relationship to both the pool of potential entrepreneurs and the economic health of the area. Other factors that should be positively related to formations are the general attractiveness of the area, the quality of the labor force, and the level of extant activity in the same industrial sector. The only factor in this list that should discourage formations (i.e., be negatively related to) is the cost of doing business.

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[31] Formation rates are calculated as the gross number of new establishments opened per 1,000 workers in the metropolitan area in 1976. Employment growth rates were calculated as the ratio of employment in 1980 to employment in 1976 for each metropolitan area for each industrial sector.

[32] The multiplicative form assumes that the percent differences in the independent variables are related to the percent differences in the dependent variables. Thus, the coefficients may be interpreted as elasticities. A coefficient of two, for instance, on a variable measuring educational level in a formation equation means that each one percent change in education level is associated with a 2 percent change in formations, on average, allowing for the simultaneous effect of the other independent variables.

Of the measures included in the Metropolitan Area Aggregate Data Base described earlier, several can be considered indicators of the size of the pool of entrepreneurs. For all industrial sectors, the proportion of the adult population with college degrees and city size should be relevant. The proportion of workers in scientific, technical, and professional occupations is probably the best indicator of potential high-technology entrepreneurs.

The measures selected as independent variables are not discrete proxies, but often overlap as indicators of more than one of the metropolitan characteristics. Both the educational variable and the technical skills variable also provide a measure of the quality of the available labor force, which should be important for both formations and growth in high-technology industries. The proportion of the labor force in manufacturing and the share in the relevant industrial sector have been suggested as better indicators of the supply of appropriately skilled labor.

Differences in the strength of the metropolitan economy would be reflected in the differences in growth in each sector, ceteris paribus. Since the high-technology sector is a very small portion of the total (7.4 percent of total employment on average), it is reasonable to assume that the two different measures of the strength of area economies used, area employment growth rates and area employment rates are exogenous.[33] This assumption cannot be made for the "other industries" sector.

The association of high-technology growth and demographic characteristics of the metropolitan areas has been the subject of much speculation and little testing. It has been suggested that a higher population implies the availability of a broader range of goods and services which are needed to support high-technology growth. The relationship of population density to high-technology growth could be either positive, as an indicator of desirable concentration of support services, or negative, as a measure of stagnation and lack of expansion potential of a city.

Differences in the proportion of employment in manufacturing have similarly dichotomized interpretations. They might represent dependence on older, declining manufacturing industries with a large proportion of unionized, high wage labor or, conversely, the greater availability of skilled manufacturing workers, support services, and other desirable infrastructure. In "other industries" differences in population growth rates were expected to be proportional to differences in employment growth rates since that sector provides consumer goods and services for the expanding population.

Assuming businesses try to maximize profitability by minimizing costs, the rates of formation should be inversely related to the indicators of business costs. Three business cost measures were used—average hourly wages for manufacturing production workers in 1976, average monthly commercial electricity bills in 1976, and an index of per-capita local taxes in 1977. Wage rates were expected to exhibit the strongest negative association because they represent a much larger portion of variable costs than the other measures used here.

The level of existing activity in each industrial sector (or sector strength) was expressed either in terms of size (number of employees in the sector) or in terms of sector share (proportion of 1976 employment in that sector). A large agglomeration effect in high-technology business formations was anticipated in the form of a strong relationship between sector size and formations. New high-technology businesses were expected to favor locating near successful establishments in the same industries, where they could take advantage of the concentration of specialized support services, supply arrangements, and technically trained workers, as well as keep abreast of the activities of their competitors.

The general formulation of the equations, which are specified by the coefficients in tables B-15 and B-16, did exhibit excellent statistical explanatory qualities. The measures of relative business costs, however, were overwhelmed by the measures of regional economic strength. Overall employment growth is related to the business cost variables in much the same way as business formations are—i.e., the three business cost variables may be thought of as partial predictors of employment growth rates.[34] Previous period population growth likewise eliminated the significance of two of the three business cost variables. Consequently, alternative models were estimated in order to evaluate separately the relative importance of the business cost differences. Version A of the equations omits the employment growth variable and includes all three of the business cost variables. Version B of the equations includes the employment growth variable and the population growth variable (for formations), but drops the insignificant business cost variables. Only the electricity cost variable was retained in the formation equations. Making explicit use of employment growth alternately in place of or in addition to business cost variables has the effect of explaining sectoral deviations from average growth rates.

Although the two measures of regional economic health showed very similar elasticities, the employment growth variable performed better. However, its usefulness deteriorates with increases in the sector size. It has little actual significance in the formation and growth equations for "other industries" because that sector is so large that its growth is almost identical to the total growth.

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[33] Employment rates were calculated as one minus the unemployment rate.

[34] For all sectors together in our sample,

$\ln \text{growth} = 1.29 - 0.17\ (\ln \text{electric costs}) - 0.12\ (\ln \text{local tax}) - 0.22\ (\ln \text{wages})$; but this only accounts for 40 percent of the variation in metropolitan employment growth rates.

Table B-15.—Regression Coefficients for 1976-80 Business Formations[a]

	High technology	Low technology	Other industries
Version A:			
Technical skills	2.27 (5.86)	0.75 (2.08)	0.04 (0.14)
1976 wages	−0.96 (−2.13)	−1.10 (−2.62)	−0.61 (−1.74)
Local taxes	−0.25 (−1.27)	−0.50 (−2.64)	−0.31 (−2.01)
Electric costs	−0.46 (−2.09)	−0.53 (−2.60)	−0.29 (−1.72)
City size	0.25 (2.98)	0.19 (2.41)	−0.07 (−1.09)
R squared	0.61	0.50	0.45
Variation B:			
Population growth	3.82 (6.19)	4.14 (7.80)	2.58 (5.54)
Technical skills	1.88 (7.49)	0.34 (1.56)	−0.31 (−1.65)
Employment growth	0.74 (1.08)	0.99 (2.61)	1.03 (3.08)
Electric costs	−0.23 (−1.64)	−0.29 (−2.38)	−0.09 (−0.82)
City size	0.28 (5.87)	0.21 (4.99)	−0.04 (−1.00)
R squared	0.86	0.84	0.82

[a] Log linear regression was used on the ratio of business formations to local employment in 1976; therefore, the coefficients are elasticities. The t statistics are shown in parentheses.

SOURCE: Office of Technology Assessment.

Table B-16.—Regression Coefficients for Employment Growth[a]

	High technology	Low technology	Other industries
Version A:			
Technical skills	0.38 (1.37)	0.28 (2.57)	0.14 (1.17)
1976 wages	−0.66 (−2.21)	−0.13 (−1.05)	−0.18 (−1.33)
Local taxes	−0.28 (−1.92)	−0.07 (−1.18)	−0.08 (−1.26)
Electric costs	−0.38 (−2.52)	−0.16 (−2.68)	−0.15 (−2.21)
R squared	0.45	0.41	0.31
Variation B:			
Technical skills	1.07 (3.83)	0.03 (0.30)	−0.11 (−2.07)
Employment growth	0.88 (2.89)	0.56 (4.60)	1.06 (14.46)
Sector share	−0.34 (−5.36)	−0.16 (−2.57)	−0.12 (−1.59)
R squared	0.66	0.65	0.90

[a] Log linear regression was used on the ratio of 1980 to 1976 employment; therefore, the coefficients are elasticities. The t statistics are shown in parentheses.

SOURCE: Office of Technology Assessment.

The principal two alternative measures of labor quality also behaved similarly. The technical skills measure clearly explained more of the variation in high-technology growth and formations. Further, it better differentiates the behavior of the three industrial sectors, so the alternative measure (proportion of adult population with at least 4 years of college) was dropped from the equation.

Finally, most analyses of employment growth have used sector size as the scale variable for growth. That implicit assumption of proportionality was tested; sector size, along with the other independent variables was used to explain variance in the number of employees in 1980. Indeed, sector size had an estimated multiplicative coefficient very close to one for all sectors. Consequently, it was shifted to the left side of the equation, converting growth to growth rates, with virtually no change in the rest of the estimated coefficients.

Both versions of the formation and growth equations estimated for three different industry sectors and for two extreme firm size classes are presented in tables B-15 through B-18. Only for the high- and low-technology sectors were business size distinctions investigated. The two firm size classes examined were "tiny" businesses (establishments in firms with less than 20 employees) distinguished from "large" businesses (establishments in firms with at least 100 employees). These two size classes are highly correlated with discrete business organization types: most tiny businesses are independent single establishment firms, and most large business establishments are affiliates of multiestablishment firms. Thus differences between the size classes can also be interpreted as differences in behavior of these two organizational types.

Business Formations in Metropolitan Areas

The number of new business formations and the net increase in the number of employees in a metropolitan area should both be proportional to the size of the metropolitan area. When estimating equations for the number of new business formations in an industrial sector,

Table B-17.—Regression Coefficients for 1976-80 Business Formations[a]

	High-technology establishments		Low-technology establishments	
	Tiny firm	Large firm	Tiny firm	Large firm
Version A:				
Technical skills	2.54 (5.27)	1.74 (3.96)	0.88 (2.24)	0.15 (0.48)
1976 wages	−0.98 (−1.76)	−0.76 (−1.48)	−1.18 (−2.51)	−0.61 (−1.68)
Local taxes	−0.34 (−1.34)	−0.10 (−0.44)	−0.52 (−2.54)	−0.40 (−2.45)
Electric costs	−0.61 (−2.25)	−0.32 (−1.27)	−0.59 (2.64)	−0.26 (−1.45)
City size	0.29 (2.80)	0.21 (2.23)	0.18 (2.17)	0.13 (1.90)
R squared	0.57	0.40	0.50	0.32
Variation B:				
Population growth	4.66 (5.62)	2.86 (3.28)	4.43 (7.32)	2.75 (5.09)
Technical skills	2.13 (6.33)	1.31 (3.70)	0.45 (1.82)	−0.20 (−0.89)
Employment growth	0.59 (1.00)	1.07 (1.71)	0.99 (2.29)	1.04 (2.69)
Electric costs	−0.42 (−2.21)	−0.04 (−0.19)	−0.33 (−2.41)	−0.07 (−0.55)
City size	0.33 (5.14)	0.26 (3.83)	0.20 (4.27)	0.16 (3.75)
R squared	0.81	0.66	0.83	0.71

[a] Log linear regression was used on the ratio of business formations to local employment in 1976; therefore, the coefficients are elasticities. The t statistics are shown in parentheses.

SOURCE: Office of Technology Assessment.

Table B-18.—Regression Coefficients for Employment Growth[a]

	High-technology establishments		Low-technology establishments	
	Tiny firm	Large firm	Tiny firm	Large firm
Version A:				
Technical skills	0.58 (3.47)	0.39 (1.24)	0.21 (2.17)	0.28 (2.22)
1976 wages	−0.39 (−2.10)	−0.68 (−1.99)	−0.06 (−0.59)	−0.08 (−0.61)
Local taxes	0.12 (1.38)	−0.33 (−2.01)	−0.08 (−1.45)	−0.05 (−0.70)
Electric costs	−0.23 (−2.51)	−0.39 (−2.30)	−0.10 (−1.91)	−0.18 (−2.69)
R squared	0.41	0.42	0.33	0.34
Variation B:				
Technical skills	0.31 (1.43)	1.18 (3.71)	0.07 (0.75)	−0.02 (−1.4)
Employment growth	0.71 (3.02)	0.90 (2.58)	0.47 (3.70)	0.61 (4.13)
Sector share	0.03 (0.67)	−0.39 (−5.25)	−0.05 (−0.76)	−0.13 (−1.74)
R squared	0.41	0.64	0.47	0.55

[a] Log linear regression was used on the ratio of 1980 to 1976 employment; therefore, the coefficients are elasticities. The t statistics are shown in parentheses.

SOURCE: Office of Technology Assessment.

the overall level of employment in 1976 had a coefficient very close to one for all sectors.[35] This was not true for the number of establishments in the sector in 1976, which is the customary scale variable used to create formation rates. Therefore, the 1976 employment was moved to the left side of the equation and formations per 1,000 workers were analyzed. Both versions of the equations accounting for metropolitan differences in formation rates are shown in table B-12 for the industry sectors.[36]

Previous period population growth was the factor most strongly related to business formations in both the high- and low-technology sectors. Representing an amalgam of amenities—climate, perceived job opportunities, and other attractions, population growth exhibited the highest coefficients (elasticities) in the regression equations. Each 1-percent difference in this variable accounted for a 4-percent difference in formation rates. The high-technology formation rates were slightly less sensitive than the low-technology's to differences in previous period population growth. Formations in the "other industries" sector were not related to previous period population growth. The consumer goods and service establishments which dominate that sector might perhaps be more strongly responsive to the increased demand associated with concurrent population expansion.[37]

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[35] This measure of gross formations is quite different from the net increase in number of establishments, which would be derived from comparing aggregate data for two observation points.

[36] Regression results for formations in the high-growth, high-technology sector were essentially identical to those for the whole high-technology sector.

[37] A recent study of the relationship between population migration and job migration found that during the 1960's, "jobs followed people quite strongly, and people followed jobs less completely." See Katharine Bradbury, et al., *Urban Decline and the Future of American Cities* (Washington, DC: The Brookings Institution, 1982), pp. 103-104.

The quality of the labor supply and the pool of potential entrepreneurs, as measured by the proportion of workers using scientific and technical skills, were expected to be more important in explaining differences in high-technology formations. The results strongly supported this expectation; each percent (not percentage point) difference in the local share of technical occupations accounted for a 2-percent difference in formation rate in high technology.[38] As anticipated, in the low-technology sector the effect was much smaller, and in the "other industries" sector it was insignificant and close to zero.

The three business cost variables used in Version A all had the expected negative coefficients, and all were significant in both the high- and low-technology sector equations, except for impact of local taxes. The negative impact of local taxes was significant in the low-technology and the "other industries" sectors, but not significant in the high-technology sectors. The relationship of local taxes to business development is unclear both theoretically and empirically. It is possible that local taxes have no measurable effect on high-technology formations because their negative impact in terms of business costs is offset by the symmetrical positive impact of local government expenditures. Nonetheless, this lack of a strong relationship corroborates the findings of other analyses concerning the relationship of local taxes and business formation rates.[39] Local differences in wage levels were inversely proportional to differences in high- and low-technology establishment formations. Formation rates twice as sensitive to wage rate differences as to the other measures of business costs. For the "other industries" sector, the relationship of formations to these business cost variables was similar, but of smaller magnitude. Again this lower sensitivity to local differences is probably attributable to the large proportion of this sector which serves local markets, making principally intrametropolitan location decisions.

When metropolitan employment growth was added to the equation to create Version B (see table B-15), it captured most of the business cost differences, leaving only small coefficients for electric utility rates. In other words, overall employment growth is strongly related to these business cost variables in the same direction as are business formations. Utility rates did have an impact in excess of that assumed by employment growth differences in the manufacturing and business service sectors, but not in the "other industries" sector, which are less dependent on energy inputs.[40]

New business formations as a whole were roughly proportional to employment growth, as expected, since they are a major component of net employment growth. High-technology formation rates varied three-quarters of 1 percent for each 1-percent difference in the strength of the local economy, measured by employment growth rates.[41] While the regional analysis above indicated a strong and close relationship between regional employment growth rates and high-technology growth rates, that relationship became less clear at the metropolitan level. The simple correlation of high-technology formations with metropolitan employment growth was small and negative. However, it is reassuring that the regressions, which simultaneously take into account other important factors, reconfirm the close association between high-technology development and net employment growth rates.

City size had a small, but significant, positive association with formation rates in both the high- and low-technology sectors. The impact and significance of city size increases greatly when previous period population growth is also taken into consideration. The larger of the expanding metropolitan areas experienced more high- and low-technology formations. City size is highly correlated with cultural and social amenities often cited as significant attractions to high-technology firms and their prospective employees. The greater diversity of goods and services available in larger cities apparently provides more advantages to new manufacturing and business service establishments than the offsetting small city advantages, such as lower land costs, better city planning, and less congestion. City size had no measurable impact on formations in the "other industries." This divergence in the behavior of the manufacturing and business service sectors from that of the "other industries" sector is noteworthy because of the dominant size of the "other industries." A recent study of urban decline for a larger sample of SMSAs found city size to have a significant negative impact on intermetropolitan business location decisions.[42]

The expected agglomeration effect was not discernible in terms of a relationship of differences in formations to differences in relative size of the sector.[43] Neither the high-technology sector as a whole, nor the smaller subsector of high-growth/high-technology industries exhibited a strong relationship to sector share. Nor was there the expected association between differences in the absolute level of employment in the high-technology sector and the business formation rate, after taking into account the other differences between the metropolitan areas. It is possible that the scientific and technical share of local employment, which is already in the equation, captured any agglomeration effect present. Relationships to relative sector size might surface in an analysis of growth dynamics for more narrowly defined, individual industries.

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[38] For example, there is a 5-percent difference in technical shares between a city with 20 percent technical and with 21 percent technical.

[39] See, for example, Michael Kieschnick, *Taxes and Growth: Business Incentives and Economic Development* (Washington, DC: Council of State Planning Agencies, 1981); and Dennis W. Carlton, "The Location and Employment Choices of New Firms: An Econometric Model With Discrete and Continuous Endogenous Variables," *Review of Economics and Statistics*, September 1983.

[40] Also, recall that the "other industries" sector is dominated by predominantly small local operations which give less consideration to alternative locations.

[41] As mentioned earlier, the high-technology sector employment is such a small portion of the total labor force that net employment growth in a metropolitan area can be considered exogenous to it.

[42] Bradbury, et al., op. cit., pp. 209-210.

[43] The employment in high-technology establishments as a percentage of the total private sector employment in all nongovernmental industries in the SMSA.

The other two demographic variables, percent of employment in manufacturing and population density, were not significant in any version of either the formation or growth equations.[44] Differences in city size might supplant the relevant aspects of these urban structure variables.

The Version A equations, which exclude the variables for metropolitan employment and population growth rates, still explained well over half of the variation in high-technology formation rates and in low-technology formations. The proportion of scientific and technical occupations and the average wage levels together accounted for 45 percent of the explained differences in high-technology formations, but only 16 percent of the explained differences in the other two industrial sectors. Version B effectively addressed the deviation of some sectors' formation rates from the overall metropolitan growth rate. Sector deviations resulted, principally, from differences in sensitivity to previous period population growth rates and the availability of technically skilled labor. These two factors, along with city size and electricity costs, explained over 80 percent of the variation in each sector's formation rates. In sum, high-technology formations were distinguished from formations in the other two sectors by a much greater sensitivity to the share of scientific and technical occupations in the work force and a somewhat greater sensitivity to city size.

Employment Growth in Metropolitan Areas

It is more difficult to explain the differences in employment growth rates, because they frequently represent a rather small net difference between large positive flows (of jobs from formations and expansions) and large negative flows (of job losses from closures and contractions). The negative flows are less variable than the positive flows so the intermetropolitan differences in net growth rates may usefully be viewed as a function of their gross formation and expansion rates.[45] Thus one would expect many relationships to be similar to those found for the formation rates, but generally weaker. Sector employment in the area was used to scale the growth numbers. Growth rates are expressed as the ratio of 1980 employment to 1976 employment, centering the measure on 1.0, so the percent changes in growth rates are similar to percentage point differences.

As with the formations equations, two versions of the model explaining net employment growth are presented in table B-15 for each industrial sector.[46] Version A, excluding overall metropolitan employment growth rates, shows the business cost variables are generally significant with negative coefficients. Most of the coefficients are smaller than their counterparts in the formation equations, indicating that net employment growth rates were less sensitive to costs than were formation rates. Electricity costs had significant, negative coefficients for all three industrial sectors. Local tax rates were insignificant for all three, and wage rates were significant only for the high-technology sector.

The technical skills variable is much less important in explaining net employment growth in the high-technology sector than it was for high-technology formations. This probably results from the different characteristics of the firms, or industries, dominating these two measures. Employment growth in the high-technology sector would primarily reflect entry into or expansion of large production facilities which require relatively smaller proportions of scientific and technical personnel. In contrast, formations are numerically concentrated in smaller independent operations, which in the high-technology sector would rely heavily on such skilled employees.

Interpreting Version B as an explanation of the deviation of sector growth rates from the overall metropolitan growth rate, it is not surprising that the technical skills variable remains the most important distinguishing fact or in explaining high-technology development.[47]

In the employment growth equations, sector share surprisingly had a negative coefficient. If a sector is 3 percent (not percentage points) larger than average, the net employment growth rate would be expected to be 1 percent lower than otherwise. While it is tempting to label this a negative agglomeration effect, the level of industry aggregation is possibly too broad to measure accurately agglomeration economies. Furthermore, the inclusion of the technical skills variable, measuring the proportion of the total work force in scientific and technical occupations, may capture a significant portion of such effects. This negative relationship to sector share more likely reflects a tendency towards some optimal mix of industrial sectors or shifts of certain high-technology industries (or firms) across stages of the product lifecycle. Those areas with large existing high-technology sectors may suffer from a relative scarcity of technically skilled labor to support further profitable development. Additionally, shifts into the mass production stage may elevate other considerations above the desirability of locating near an existing nexus of high-technology businesses.

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[44] Population density was also found to be unimportant with respect to business location decisions in Bradbury, et al., op. cit., p. 103.

[45] See the regional analysis above and Catherine Armington, "Further Examination of the Sources of Employment Growth," Working Paper No. 12, Business Microdata Project, The Brookings Institution, March 1983.

[46] Again the regression results for the high-growth, high-technology subsector were essentially the same as for the entire high-technology sector. The proportion of variation explained was somewhat lower. The low-growth, high-technology subsector lost 1.3 percent of its employment between 1976 and 1980.

[47] Remember that differences in growth rates are a function of the positive growth components (formations and expansions).

Special Characteristics of Small High-Technology Firms

Businesses with different organizational and managerial structures might be expected to employ different sets of criteria in deciding on locations for new operations. A multiestablishment firm, with a scope of operations spanning several States and industries, may not be influenced by the same factors as a small-scale entrepreneur seeking to set up a new independent business. Existing businesses frequently chose to expand their operations by opening new branch establishments. Such formations may supplement or replace the firm's capacity in their current business activity or extend their operations into new industries or product lines. If a firm opens a new branch establishment in the same State in which its operations are centered, the location decision is likely a matter of production necessity or managerial convenience. On the other hand, larger multiestablishment firms which choose to open branch establishments in distant locations should be making such decisions on the basis of profit-maximization. Metropolitan differences in these formations of new establishments by large firms would then be more closely associated with factors measuring the relative business costs and benefits.

For establishment formations in large firms in the high-technology sector, the most important associated variable was the previous period population growth (see table B-16.) This was followed by the technical skills variable and the overall employment growth measure. The relationships between the rate of formations and these factors were strongly positive and significant. The remainder of the explained variation was attributable to a small positive relationship with the city size (1976 population). Contrary to expectation, formations in large firms were not strongly related to variations in business costs, as measured by local taxes, wage rates, and electricity costs. Though the relationships were all of the proper negative direction, only the wage-related costs approached significance. For large firms in the low-technology sector, the pattern of association between establishment formations and the metropolitan characteristics was similar, with the notable exception of the technical skills variable. Formations in large low-technology firms were negatively related to the proportion of jobs in scientific, technical, and professional occupations, but this was a weak and insignificant relationship.

Smaller businesses, which include most independent establishments, usually locate in the locale familiar to the entrepreneur. Distant alternative sites are rarely considered for initial locations. The primary factors expected to be associated with variations in formations of small, independent businesses are those affecting the supply of potential entrepreneurs and their financial ability to start a business. Reflecting the pool of potential entrepreneurs, a strong positive relationship was anticipated between the formation rate of tiny high-technology firms and the percent of the labor force in technical and scientific occupations and the previous period population growth. Formations in tiny firms were further expected to exhibit the relationships to business costs and other variables demonstrated to be significant for the business population at large.

Indeed, the results of the regression analysis for the population of establishments in tiny firms supported all the expected relationships. New formations in tiny firms in both high-technology industries and low-technology manufacturing and business services had a strong positive relationship to previous period population growth. Intermetropolitan differences in the formation rates of tiny firms are also related to differences in the levels of technical skills. These relationships were significant and much stronger for tiny firm formations than they were for large firms. This supports earlier findings that indicate large firms are less dependent on the existing technical expertise in selecting their sites for new operations.

Formations in tiny firms were consistently negatively associated with the variations in wage rates, electricity costs, and local tax rates. High business costs may be more constraining to small firms than to large firms. Large firms often have a financial and managerial infrastructure that permits them to absorb higher costs or to pass them through in the form of higher priced output. Furthermore, their volume of business enables them to obtain certain concessions which might not be available to smaller firms.

Formations in tiny firms are more sensitive to differences in many of the metropolitan characteristics. These factors accounted for 81 percent of the variation in tiny firm formation rates, but only 66 percent of variation in formations of large high-technology firms. The most important predictor for both size classes in both the high- and the low-technology sectors was previous period population growth. Although it had only a small effect, city size was also significantly related to formations, more strongly for large firms than for small. In the high-technology sector, formations in both size classes were very sensitive to the availability of scientific and technical workers. Business costs were much more important in explaining variations informations in tiny firms than they were for formations in large firms in both high- and low-technology industries. Finally, high-technology formation rates in large firms were twice as sensitive to our measure of local economic strength—overall employment growth.[48]

In both high- and low-technology industries, employment growth rates were generally much higher in tiny firms than in large firms (see table B-17). While the relationships between formations in large firms and the business cost variables were not significant, employment growth did exhibit a significant negative relationship to the business cost variables. Employment growth rates in existing tiny firms are generally less sensitive than the rates in large firm establishments to all significant metropolitan variables.

In high-technology establishments of large firms, growth is particularly responsive to variations in the strength of the local economy and in the supply of technically skilled labor. More notably, their growth rates show a significant negative association with sector share, while tiny firm growth was virtually independent of that factor. This discrepancy in the relationship of small and large firm growth to the size of the high-technology sector is possibly a reflection of product cycle differences. Employment growth in large high-technology firms is most likely manifested in the establishment of large manufacturing plants, once production has become standardized. Such production facilities would likely reap more benefits from inexpensive factor prices than from an established concentration of high-technology businesses competing for the same manufacturing production workers. Again a more disaggregated analysis at the four-digit industry level for more narrowly defined geographic areas would help to clarify some of these issues.

Summary of Analysis

Recent publicity about rapid growth of employment in high-technology industries has caught the attention of policymakers at all levels of government. Many State and local governments have already created programs to encourage the formation and growth of new high-technology businesses in their regions. While calls abound for policies promoting development of high-technology industries, there is a dearth of empirical information on the efficacy of such programs. This study has provided an empirical description of the high-technology sector, its employment growth patterns, and the association between the locus of high-technology growth and particular characteristics of metropolitan areas, utilizing the U.S. Establishment and Enterprise Microdata (USEEM) recently developed at The Brookings Institution.

Adopting a broad definition of high-technology industries, based on minimum levels of professional, scientific, and technical workers or of R&D expenditures relative to total sales in each industry, a total of 88 high-technology industries were identified in manufacturing and business services. Longitudinal tabulations of the business microdata provided data for analysis of the high-technology sector in 1976 and its growth from 1976 to 1980. Employment growth and business formation data were extracted from these tabulations and integrated with other socioeconomic data for a sample of 35 metropolitan areas. These aggregate data were then used to examine the relationships between the characteristics of the metropolitan areas in the sample and the formation and growth of high-technology establishments. Data for the high-technology sector were contrasted with those for the rest of the manufacturing and business service industries (called "low technology") and with "other industries" (excluding manufacturing, business services and government).

Through descriptive analysis of the regional tabulations and regression analysis of metropolitan data the following questions were addressed: What are the characteristics of high-technology establishments and their patterns of employment growth? How does the distribution and behavior of high-technology establishments differ from that of establishments in other industries? Are there particular characteristics of metropolitan areas that seem to favor the formation and growth of high-technology industries?

Analytic Findings

The high-technology sector contains only a small part of the Nation's jobs; it employed 5.6 million workers in 1976 and 6.7 million in 1980. Business services accounted for around 15 percent of the high-technology employment. Aside from their shared dependence on evolving technologies, the industries in the high-technology sector are far from homogeneous. As in nearly all industries, most high-technology businesses are very small; more than half of the high-technology establishments are in firms with fewer than 20 employees. However, far more than other industries, the high-technology sector's employment is concentrated in large firms, spanning both producers and consumers of high-technology products and processes. Statistically, the dynamic entrepreneurs with small high-technology companies are overwhelmed by large-scale, high-technology production in existing businesses.

- The sector includes industries and firms within industries in every phase of their product cycles, from the innovation and testing phase to large-scale, standardized production.

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[48] Other studies have found large firms to be more sensitive to cyclical fluctuations in general economic activity than small business. See, for example, Victor Zarnowitz, "Cyclical Aspects of Incorporations and the Formation of New Business Enterprises," and Victor Zarnowitz and Lionel Lerner, "Cyclical Changes in Business Failures and Corporate Profits," in *Business Cycle Indicators: Volume 1*, Geoffrey Moore (ed.) (Princeton, NJ: Princeton University Press, 1961).

- About 90 percent of high-technology employment is in firms with at least 100 employees. High-technology establishments are on average five times the size of establishments in other industries.
- More than half of the sector's employment is in branch establishments of firms which are headquartered out-of-State.
- The distribution of high-technology jobs across the four regions of the United States fits the same general pattern as employment in all industries.
- Within regions the importance of high-technology industries in the local labor force ranged from 6 percent in the South to 9 percent in the Northeast.

High-Technology Employment Growth.—The interest in high-technology industries has centered largely on their potential for generating new employment opportunities. Indeed, employment in that sector grew 19.4 percent between 1976 and 1980, about 66 percent faster than the low-technology industries. However, patterns of recent employment change vary widely for industries within this sector. Some experienced mercurial employment growth (e.g., computer programming grew more than 75 percent in the 4 years) and others dramatic shrinkage (e.g., electronic capacitor manufacturing which reduced employment by more than 50 percent).

Dividing the high-technology industries into high- and low-growth subsets, the 55 industries in the high-growth subset grew 30.6 percent between 1976 and 1980.[49] The low-growth, high-technology subset lost employment, indicating that technological advance is not necessarily associated with employment generation. This wide variation in growth rates across industries reflects changes in labor requirements as firms within these industries move through their different stages of their product lifecycle and also the rapid processes of technological change which can render certain product lines obsolete.[50] In sum,

- Growth rates in the high-technology sector were 66 percent higher than in low-technology industries, but the small size of the sector limits its current contribution to net job creation (about 1.1 million of the 11.5 million created between 1976 and 1980).
- Within the sector, employment growth rates vary widely across industries. Despite high average growth rates for the sector, almost one-fourth of the high-technology industries experienced net losses of employment between 1976 and 1980.

Regional Aspects of Growth.—Employment growth rates vary more widely across regions than across industrial sectors. In other words, the performance of the region tends to overshadow differences in industry performance. If a region is experiencing relatively high growth in the high-technology sector compared to the national average, it is likely to have higher growth rates in other sectors.

The regional trends in the growth of high-technology employment conformed with development theories of regional convergence due to factor price equalization. The regions which experienced the highest rates of growth were those which previously had the smallest shares of high-technology employment—i.e., the South and the West. Regional growth in the low-technology sector was similarly distributed.[51] The tendency toward equalizing the regional shares of high-technology employment observed here is similar to findings of other studies of regional development in the 1970's.[52]

Since rates of employment loss due to business closings and contractions are relatively constant for all regions, regional differences in high-technology growth are largely a function of formation rates. Each region's share of business formations was similar across industrial sectors. The Northeast, for example, had 20 percent of all high-technology formations, 19 percent of all low-technology formations, and 20 percent of all "other industries" formations.

To reiterate, the major findings regarding the broad regional distribution of high-technology growth are as follows:

- A region's high-technology growth is largely a reflection of its overall economic performance.
- There appears to be a redistributive effect in that those regions with the smallest shares of high-technology employment experienced higher growth rates.
- Growth depends primarily on business formations; a region tends to capture approximately the same share of formations in each industry sector.

Organizational Aspects of Growth.—A popular conception of the high-technology sector links its rapid expansion of employment to successful small independent firms.[53] In fact, independent firms in all industrial sectors did have much higher growth rates than affiliates of larger firms. Moreover, the performance of high-technology independents far outstripped their counterparts in the other sectors. The evolutionary nature of this sector seems to favor independent firms more than the mature, stable structure of the industries in the low-technology sector.

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[49] Defined as above or below the all-industry average of 15.2 percent.

[50] For a thorough discussion of various employment effects associated with technological change, see C. Freeman, J. Clark, et al., *Unemployment and Technological Innovation* (New Haven, CT: Greenwood Press, 1982).

[51] It should also be noted that these regions have a comparative advantage in terms of energy supplies and costs. Some studies have found energy costs to be significant in explaining the redistribution of population and economic activity in the 1970s. See Shirley P. Burggraf, "Implications of Energy for Economic Development Planning," Monograph, National Council for Urban Economic Development, July 1981.

[52] See Jackson, et al., op. cit.; and John Rees and Howard Stafford, "A Review of Regional Growth and Industrial Location Theory: Towards Understanding the Development of High-Technology Complexes in the U.S.," paper prepared under contract for the Office of Technology Assessment, May 1983.

[53] See D. Koch, et al., "High Technology: The Southeast Reaches Out for Growth Industry," *Economic Review*, Federal Reserve Bank of Atlanta, September 1983, pp. 4-16.

Despite their dynamism, the independent firms still contain only 12 percent of the high-technology sector's employment. Though much of the innovation and the competitive stimulus in high-technology industries is probably in independent firms, the appreciable increments in employment derive from the implementation of these innovations at later stages in the product takes place in affiliates of large firms. Formations of national affiliates accounted for more than 60 percent of the employment in new high-technology establishments. Affiliates of instate firms contributed another 25 percent of such new high-technology jobs.

This study provides some evidence to support elements of the product/regional lifecycle theories. These theories suggest that certain stages of the production process have different locational requirements.[54] For instance, the high-technology sectors in the Northeast and the West have larger proportions of independents, and above average net formation rates for independents. The greater presence of independents in these regions in which high-technology industries were historically conceived and concentrated could be evidence of the "seedbed" or incubator effect often discussed in connection with the high-technology sector. In the R&D phase of the product cycle, firms would be more likely to benefit from the clustering of highly trained research and technical personnel and facilities that exist in these regions.[55] On the other hand, the South's high proportion of large production facilities owned by out-of-State firms and its higher rates of growth in such establishments probably reflects decisions to locate large, standardized production facilities in areas with low labor costs and low unionization. Further research with more detailed industrial and regional breakouts would be necessary to confirm this hypothesis.

For the present, the findings regarding organizational structure and high-technology growth can be summarized as follows:

- Independent firms have much higher growth rates than affiliated establishments, but they hold less than 12 percent of the high-technology sector's employment.
- Affiliated establishments had similar growth rates in both the high-technology and "other industries" sectors, but independent firms grew three times as fast in high-technology compared to "other industries."
- The South has an exceedingly high proportion of employment in national affiliates in all industrial sectors, particularly in high-technology industries.
- The high-technology employment growth rate of local affiliates was more than 50 percent higher than that of national affiliates. Only in the South were national affiliates growing more rapidly than local affiliates.

Formations and Metropolitan Characteristics.—An analysis of metropolitan business formation and growth in the three sectors in relation to several metropolitan characteristics was conducted to illuminate the dynamics behind these regional trends and perhaps to identify characteristics that communities might develop to foster high-technology development. As other studies of high-technology have found, high-technology businesses behave much the same as other businesses in choosing sites for their operations. Businesses are attracted to areas with lower business costs, with healthy local economies, and with a relatively attractive quality of life.

What differentiates the location decisions of high-technology firms is the greater importance of an educated, skilled labor force and local amenities.[56] This again coincides with numerous studies surveying high-technology firms, in which they identified labor considerations as their primary concern.[57]

- Each sector's formation rates were inversely related to local business costs—wages, local taxes, and electricity costs.
- Metropolitan differences in business formations in all sectors were proportional to the size of the city's labor force and to the strength of the local economy.
- Previous period population growth, an indicator of general attractiveness and growth potential, had the strongest relationship to business formations, particularly in the high- and low-technology sectors.
- The proportion of the labor force in technical occupations is strongly related to high-technology formations, but not to other sectors.
- Both high- and low-technology formations are favored slightly by larger city population sizes. City size is unrelated to formations in the "other industries" sector.
- After accounting for differences in the technical occupation share of the local labor force, the relative size of the extant high-technology sector was not related to business formations.
- Formations in the subset of high-growth, high-technology industries behaved virtually the same as the entire high-technology population in relation to the metropolitan variables.

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[54] *Encouraging High-Technology Development*, op. cit., app. B, p. B-14.

[55] See C. Freeman, *The Economics of Industrial Innovation* (Cambridge, MA: MIT Press, 1982).

[56] City size is used here as a proxy for local amenities.

[57] See Joint Economic Committee, U.S. Congress, *Location of High Technology Firms and Regional Economic Development* (Washington, DC: U.S. Government Printing Office, June 1982), and *Encouraging High-Technology Development*, op. cit., app. B.

Employment Growth and Metropolitan Characteristics.—Since business formations play an important part in employment growth it should not be surprising that the results of the analysis of employment growth were similar to the formation equations. In general, the metropolitan characteristics explained less of the variation in net employment growth rates than of the variation in formation rates. Coefficients (elasticities) are lower, and fewer variables are significant.

- Business costs were negatively related to growth in all sectors, but were significant only for the high-technology sector.
- The proportion of scientific and technical workers was again most important and significant for the high-technology sector.
- Surprisingly, sector share had a significant negative association with high- and low-technology growth. This lends further support to regional convergence tendencies mentioned above.
- The high-growth, high-technology subsector behaved essentially the same as the entire high-technology sector, but less of the variation in its growth was explained.

Business Size Considerations.—Businesses with different organizational and managerial structures might be expected to employ different sets of criteria in deciding on locations for new operations. Therefore, relationships were separately estimated for tiny firm formations and for establishment formations in large firms in high technology.[58] The direction of the relationships was generally the same, but the elasticities were consistently higher for tiny firms than for large firms:

- Formations of tiny high-technology firms were almost twice as responsive as formations in large firms to variations in previous period population growth, the share of scientific and technical workers, and most business cost variables.
- Formations in both size classes of high-technology firms showed the expected strong relationship to technical skills; that factor was insignificant for low-technology formations.
- Overall employment growth, the exception, was more strongly related to formations in large firms.[59]

Employment growth rates in tiny firms were much higher than in large firms in both the high- and low-technology sectors, which is partly a function of their smaller base employment. Contrary to the tendencies in formations, establishment employment growth in tiny firms was less sensitive than that in large firms to almost all the significant metropolitan variables. Also, less of the variation in net growth was explained for tiny firms. Growth of high-technology employment in establishments in large firms was particularly responsive to variations in the strength of the local economy and in the supply of technically skilled labor. Unexpectedly, large firm establishment growth showed a small, but significant, negative relationship to relative sector size. As discussed above, this could reflect the stage of the product lifecycle at which large employment increases occur.

Data Limitations and Analytic Considerations

The initial difficulty encountered in studying high-technology development is the selection of a satisfactory definition of high technology and the criteria for choosing the industries to be included in that category. Business data are primarily available aggregated by industrial classifications. Industry classes comprise groups of firms producing a wide variety of products with production processes of differing technological content, thus obscuring important differences among firms within each industrial grouping.

With this shortcoming in mind, a definition based on occupational composition of industrial classes was selected—one which in turn has its own limitations. The occupational data are only available at the three-digit level of standard industrial classification. Some of these three-digit groupings contain four-digit component industries which would not qualify as high-technology industries. The absence of more detailed data on occupational composition led to a subjective editing which eliminated eight of the four-digit industry classes in the three-digit business service groups identified with the established criterion. These subjective adjustments somewhat diminish the rigor of the definition of high technology used in this analysis. No such adjustments were made to the systematic selection of manufacturing industries.

Other problems arise from industrial classification practices. In newly emerging industries, businesses may assume indistinct classifications until revisions in the industry codes provide more appropriate alternatives. For example, the two largest robotics manufacturers are in different four-digit SIC groupings; one is in a general "not elsewhere classified" category. In sum, industrial classes are not the most desirable unit of analysis for the definition and study of innovation and development in high-technology industries, but data availability currently dictates their use.

Further problems of aggregation arise in analyzing the "high-technology sector." The common feature of the industries making up this sector is their utilization of evolving technologies and/or production of new products. The differences among these component industries are often more striking than their similarities. The heterogeneity of the sector is apparent in their differing rates of employment change during the 1976-80 period. Some high-technology industries experienced employment growth in excess of 75 percent, while other contracted their work force by as much as 50 percent. Clearly, this reflects a wide range of changes in demand, product mix, and productivity. While businesses in some industries are rationalizing their production of goods facing slackening demand, others are expanding employment rapidly in response to consumer pressures. Disaggregating the high-technology industries could reveal some important differences masked by the broad grouping.

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[58] These two size classes are approximately equivalent to the organizational categories of independents and affiliates, respectively.

[59] This might be expected since formation and failure behavior of large firms tends to be much more sensitive to long term and to cyclical fluctuations in the economy. See Candee Harris, "Icebergs and Business Statistics: A Comparison of Data for Failures and Dissolutions," Business Microdata Project, The Brookings Institution, draft, September 1983.

A partial step was taken in this direction by dividing the sector into high- and low-growth industries based on their divergence from average employment growth rates between 1976 and 1980. The high-growth subset of the high-technology sector accounted for 75 percent of the business formations and all of the net employment growth for the period studied. The 35 slower growing industries as a group lost 1.3 percent of their employment. However, among the high-technology industries experiencing low or negative employment growth are several industries with growing levels of output. For example, electronic capacitors increased output by 16 percent between 1976 and 1979, despite reducing its employment by more than 50 percent. Similarly, synthetic fibers marked a 4-percent decline in employment, but an 18-percent increase in output and a 6-percent increase in productivity.[60] Further analysis is needed of the dynamics of component industries of the high-technology sector, taking into account differences in their predominant state of production.

Another limitation of this study derives from the procedures for classifying business establishments. Enterprise employment size, geographic location, organization type, and industry are determined by the 1976 data on establishments. New business formations were not in the 1976 file; therefore, the characteristics of formations and their owning firms are drawn from the 1980 file. Consequently newly formed affiliates of multiestablishment firms are categorized under the size of their owning firm in 1980, somewhat distorting the firm size distribution of growth.[61] Consequently, this analysis did not address conversion of establishments to business activities in different industrial sectors, relocation of plants, or changes in ownership structure. Probably the most important of these omissions is the acquisition of high-technology businesses by national conglomerates or by local entrepreneurs is a common means of expanding current activities or entering markets or industries. However, in themselves, such acquisitions neither increase nor decrease aggregate employment. Future studies of the dynamics of high-technology development should consider the role of such changes in organizational structure.

The broadly defined regions used for comparative purposes may also be obscuring some important differences in growth patterns. Intraregional variation is lost as the characteristics of one subregion are offset by those of another in the aggregate. Less broadly defined regional groupings, such as the regional divisions defined by the Bureau of the Census or States, would certainly reveal more information on the patterns of high-technology formations and growth.

The sample of metropolitan areas used for the regression analysis was small and was not randomly selected. Since the SMSAs were chosen on the basis of diversity in the characteristics of interest, the "fit" of the regressions may be better than that produced with a random sample. The 323 SMSAs defined in 1980 include many rapidly developing areas whose populations have only recently become large enough for inclusion as SMSAs. Our sample probably underrepresents small and newer metropolitan areas because comparable business cost data were not available for many of these.

The variables used for the socioeconomic characteristics of the metropolitan areas are often averages for broad classes. For example, the tax index is calculated from a composite of all State and local taxes per capita. It is not a precise measure of the actual tax burden faced by a new business and does not explicitly take into consideration any special benefits offered by local governments to induce businesses to locate there. The wage variable is also an average for all manufacturing production workers, which may not accurately reflect intermetropolitan differences in wages for high-technology industries. As more detailed data become available, further research may clarify many of these ambiguities.

Finally, some mention must be made of the period of observation used in this analysis, which encompasses changes between December 1976 and December 1980. The secular and cyclical trends prevailing during this period include a retreat from record high inflation rates, gradually increasing unemployment and rapid increases in interest rates to record highs. Gross national product grew 5 percent between 1976 and 1977, but suffered a real decline of almost 2 percent during 1980. The rate of business failures increased from 28 per 10,000 firms from December 1976 to December 1977 to 42 per 10,000 for 1980, while the index of new firm formations declined by 5.4 percentage points over the period.[62]

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[60] U.S. Department of Labor, Bureau of Labor Statistics, *Productivity Measures for Selected Industries, 1954-81* (Washington, DC: U.S. Government Printing Office, December 1982).

[61] Acquisition of the base year data for firm size requires costly, complex processing of the data files. Preliminary analysis indicated that the degree of distortion would be minimal given the broadly defined large firm size class.

[62] These are formations and failures of enterprises, not establishments which are the primary unit of analysis in this study. Statistics are drawn from the *Statistical Abstract of the United States 1982-83*, p. 532.

It is often claimed that high-technology industries are "recession-proof," but this is likely based on the simple contrast to certain low-technology industries, such as automobiles, which are extremely recession-sensitive. In addition, the newness of products can generate demand in spite of cyclical tendencies. One can only speculate on the differing impact of cyclical conditions on and business formations in each of the three industrial sectors. Data will soon be available for the analysis of each 2-year period between 1976 and 1982, which will shed some light on the limitations of the single, 4-year observation period used in this study.

Policy Implications

Policymakers are anxious for assessments of the potential of high-technology development to ameliorate the persisting problems of high unemployment, a declining manufacturing sector and economic distress concentrated in particular cities and regions of the country. The perceived qualities of high-technology industries which are relevant to domestic employment problems are:[63]

- high rates of job generation (direct and indirect);
- better quality jobs; and
- independence of geographic constraints (i.e., hope for distressed areas).

Before suggesting policy measures aimed at promoting high-technology development, let us examine the evidence regarding these supposed benefits.

As a group, the high-technology industries have exhibited impressive growth rates in recent years. The high-technology manufacturing and business service industries grew 19.4 percent between 1976 and 1980, compared to about 12 percent for the low-technology sector.[64] High-technology manufacturing industries comprised about 20 percent of manufacturing employment in 1976 and more than 40 percent of growth in that sector through 1980. Though the smaller employment base of this sector requires the creation of relatively fewer jobs to achieve high-growth rates, its very high share of the net employment increase validates its significance. Findings of another study for a longer period confirm these trends. Between 1970 and 1980 the employment growth rate in high-technology manufacturing industries was more than 10 times that of the low-technology sector.[65]

Despite the impressive growth performance of the high-technology industries in the aggregate, the sector comprises a diverse set of industries undergoing rapid technological change with differing impacts on employment. In some industries the introduction and diffusion of new products is rapidly expanding manufacturing and supporting service jobs. In others, reductions in demand and/or increased productivity are resulting in net reductions of the work force.[66] Of the high-technology industries anlyzed in this study, one-fifth actually reduced the number of jobs they provided between 1976 and 1980.

A number of other factors can diminish the job creating potential of high-technology industries. Based on the application of evolving technologies, many high-technology products face high rates of obsolescence or failure. Adoption of new processes can lead to productivity increases, and new product lines can capture markets for existing goods, both leading to displacement of workers in other industries. Such offsetting tendencies must be incorporated into assessments of the job-generating potential of high-technology industries.

Although this analysis did not directly address the quality of jobs being generated by the high-technology sector, a few words regarding this suggested benefit seem appropriate. It is often assumed that the new employment opportunities created by the expansion of high-technology industries are better paying, less hazardous, and more personally satisfying. Again in the aggregate, the figures for high-technology industries are encouraging. In 1980 high technology's average rates of compensation of both manufacturing production workers and of all employees were higher than those in low-technology manufacturing industries. In 1980 high-technology production workers earned about 50 cents more per hour, and the average high-technology employee made $3,500 more per year than their counterparts in the low-technology manufacturing sector.[67]

As with most aggregate statistics, these figures disguise enormous discrepancies in the occupational structure and employee compensation within the industries. The proportion of scientific, engineering, and technical workers to total employment in the high-technology industries is about 18 percent.[68] It has been argued that the scarce human capital embodied in this 18 percent plus a relatively small number of other highly skilled workers, commands extremely high salaries which offset below average compensation paid a majority of production workers in the high-technology sector. As high-technology industries (and firms within industries) move through the product cycle, their employment requirements vary radically. In early stages, a small but highly trained body of scientific and engineering personnel is required. However, large employment increases most likely occur in the mass production stage, calling primarily for semiskilled workers for assembly or more skilled workers for equipment maintenance. Furthermore, the demographic characteristics of the high-technology work force suggest that new jobs created in these industries may not absorb the blue-collar production workers being displaced in declining manufacturing industries.[69] Although the evidence justifying this pessimism is by no means conclusive, such factors must be taken into acount when considering development programs targeted at high-technology industries, particularly by regions with high concentrations of declining manufacturing industries.

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[63] For a discussion of the advantages of high technology for manufacturing competitiveness and international trade, see Lawrence, op. cit.

[64] The low-technology sector's growth was considerably bolstered by the inclusion of the non-high-technology businesses services. Employment growth in the low-technology manufacturing industries was closer to 6 percent.

[65] Lawrence, op. cit., p. 141.

[66] See Freeman, Clark, et al., op cit.; and Doreen Massey and Richard Meegan, *The Anatomy of Job Loss* (London: Methuen, 1982).

[67] Lawrence, op. cit.

[68] Calculated for the three-digit SICs identified in Greene, et al., op. cit.

Another benefit claimed for high-technology businesses is their apparent independence of geographic constraints, which renders almost any locale eligible for development. High-technology industries serve national, rather than local markets, so they are theoretically less vulnerable to local economic conditions. The high value to volume ratio of their products results in low transportation costs per unit. Finally, as a group they are less energy-intensive than low-technology industries, freeing them in part from regional constraints associated with the cost and availability of energy resources.

Once again the empirical information confronts us with the heterogeneity of the high-technology sector. The industries within this sector range from highly concentrated (geographically) industries, which are resource-intensive or efficient at very large scales of production, to industries whose establishments are scattered across the country.[70] Furthermore, just as the employment requirements of high-technology industries vary with the stages of the product cycle, so can their locational requirements. As pointed out earlier, some of the variation in these locational preference functions are reflected in the different behavior of small, primarily independent firms and large branch facilities. Formation rates of small, independent firms appear to be higher where there are existing concentrations of people employed in scientific and technical occupations. Given this diversity, generalizations about the locational behavior and growth of high-technology businesses must be interpreted cautiously.

In spite of their footloose reputation and their significant presence in a multitude of communities, high-technology industries, as a group, did demonstrate some preferences in their locational behavior that might affect the success of different areas in fostering its development. In this analysis, formation rates of high-technology businesses were particularly sensitive to two factors which are not especially amenable to policy manipulation—previous period population growth and city size. Business formations and growth between 1976 and 1980 in both the high- and low-technology sectors were most strongly related to the rate of population expansion between 1970 and 1975. Evidently, the same metropolitan characteristics attracting new residents to these expanding communities are attracting new businesses.[71] People are being drawn to areas with milder climates, lower energy costs, and perceived greater economic opportunity, while they are leaving areas with high population density, high costs of living, and high unemployment. There has been a clear redistributive element to the regional patterns of the changes in population and economic activity. Those regions with relative high incomes experienced lower rates of per-capita income growth, those with large concentrations of employment experienced slower employment growth, and those with smaller high-technology sectors experienced more rapid growth in high-technology industries.[72]

In the initial formulation of the model, city size had a small positive association with formation rates in the high-technology sector, but its impact and significance increased greatly when previous period population growth was also taken into consideration. It is the larger of the expanding metropolitan areas (i.e., of those with the characteristics mentioned above) which experienced higher rates of high-technology formations.

In many respects the high-technology sector behaved like the low-technology and the "other industries" sectors. However, consistent with the findings of other studies, the one factor especially important to high-technology development was the proportion of employment in scientific, engineering, and technical occupations.[73] The formation of small, independent firms was most sensitive to this factor. Formation and expansion of high-technology businesses in an area can be constrained by the lack of qualified entrepreneurs and technicians. The importance of this variable must be underlined since it is somewhat amenable to public policy. Quality education from the primary to the postgraduate level can be an important factor in attracting prospective entrepreneurs, firms and employees in high-technology fields. The gap between the skills of the unemployed and of new entrants to the work force and the demands of the labor market will continue to grow unless substantial improvements are made in the quality and distribution of educational resources.

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[69] See Lawrence, op. cit., pp. 152-155; and Eileen Appelbaum, " 'High Tech' and the Structural Unemployment of the Eighties," unpublished paper presented at Annual Meeting of the American Economic Association, Washington, DC: Dec. 28, 1981.

[70] For a discussion of the geographic dispersion of high-technology manufacturing production, see Amy Glasmeier, Peter Hall, and Ann Markusen, "Recent Evidence on High Technology Industries' Spatial Tendencies: A Preliminary Investigation," Institute of Urban and Regional Development, University of California, app. C to this report.

[71] The wording here implies that it is primarily a function of migration patterns; however, natural increase plays an important role in explaining differences in growth rates.

[72] See Jackson, et al., op. cit.; Bradbury, et al., op. cit., pp. 89-90; and Burggraf, "Implications of Energy for Economic Development Planning," op. cit.

[73] The proportion of the adult population with 4 or more years of college was also strongly related to high-technology development, but its effect was captured by the technical occupations measure.

In the wake of intense criticism of previous education and training programs, researchers have recently completed several studies reviewing these earlier efforts and suggesting effective avenues for pursuing educational goals. With regard to secondary and postsecondary training and education, the programs deemed most effective in achieving the desired match between individual skills and economic needs are those which directly empower the individual.[74] It is argued that educational institutions, which have been the primary recipients of Federal aid in the past, are less responsive to the shifting demands of the labor market than are the individuals seeking training. Empowering individuals, by directly subsidizing their choice of appropriate educational and training investments, would be more effective.[75]

A final comment on another factor with some policy relevance for high-technology development. In this analysis, local tax rates were found to have no significant effect either on high-technology formations or on net employment growth. This lends further support to a growing body of evidence showing tax differences to be unimportant in explaining differing levels of business development.[76] Furthermore, the provision of tax incentives entails sometimes significant opportunity costs. Since there is little proof that such incentives lead to the creation of business establishments that would not otherwise have located in that locale, the community effectively subsidizes firms at the expense of foregone revenue.[77]

In conclusion, the efficacy of policies aimed only at influencing high-technology development is questionable. There is no guarantee that the high-growth industries of today will be those of the next decade. In fact, the industries included under the rubric "high technology" are an ever-changing set. Narrowly focused programs which subsidize particular groups of businesses may actually result in losses to communities through distortion of costs, foregone revenue, and other unanticipated effects. Undoubtedly, the high-technology sector is generating many employment opportunities, but the dynamics underlying this net effect are complex and must be taken into consideration if employment objectives are of tantamount concern. Policies encouraging economic growth in all sectors might be preferable to "targeting" development efforts on high technology or on any industries that are remarkable for their possibly ephemeral growth. Communities should prepare their institutions and residents to respond to the ever new social and economic contexts produced by rapid technological change. The results of this analysis indicate that improving the quality and access to education and training are a good place to begin.

Clearly, the ability of communities to stimulate local development depends in large part on the national economic climate. Macroeconomic policies which encourage entrepreneurship and investment in all sectors of the economy are a key ingredient for success in smaller geographic contexts. Policies aimed broadly at promoting research, innovation, and investment in human capital and at reducing impediments to economic growth would increase total output and thereby the potential for local development.

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[74] See Bradbury, et al., op. cit., pp. 279-286.

[75] The educational program embodied in the G.I. Bill is just such a program, and it cost effectiveness has been lauded by researchers and policymakers. A comprehensive proposal for creating such a program is presented in Roger Vaughan and June Sekera, "Investing in People," *Policy Studies Review*, vol. 2, No. 4, May 1983.

[76] See Kieschnick, op. cit.

[77] See Bennet Harrison and Sandra Kanter, "The Political Economy of States' Job Creation Business Incentives," *Journal of the American Institute of Planners*, October 1978, p. 429

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APPENDIX C

Recent Evidence on High-Technology Industries' Spatial Tendencies: A Preliminary Investigation*

Introduction

In recent years—amidst a serious recession, post-Depression levels of unemployment, and major plant closings—local, State, and Federal policymakers have looked to high-technology industries as the primary source of new jobs. Efforts to attract high-technology employment have resulted in a variety of job-creating strategies undertaken by all levels of government. As the Office of Technology Assessment's recent study shows,[1] 22 States have some type of development program designed to create and maintain new high-technology jobs. An interesting finding of this study is that for a majority of States the definition of high-technology industry remains elusive, resulting in incentive programs targeted toward any industry that creates employment.

The general assumption—that a positive relationship exists between high-technology industries and employment growth—has, with a few exceptions, gone untested to date. In order to examine the incidence of high-technology employment growth and locational tendencies, we developed a data base which is highly disaggregated on both a spatial and sectoral basis. Using the 1980 National Occupational Employment Statistics Matrix, which reports detailed industry occupational profiles, we selected a set of 29 three-digit industries which had greater than the national manufacturing average of scientific and technical occupations. These 29 industries could be disaggregated into 100 four-digit sectors.

Using the 1972 and 1977 unpublished Census of Manufactures Plant Location tapes, we compiled county-level four-digit industry tallies of manufacturing plants by employment size category.[2] In conjunction with published employment data, we estimated industry employment levels from the tapes. Cross-checking with published national industry employment and plant totals confirmed the stability of our results: estimates across the 100 industries showed less than 1-percent variation between the two employment counts. Individual industry employment estimates varied by less than 10 percent.

With this detailed data base we have been able to explore a number of commonly held views about high-technology industries. Specifically, we have examined the degree to which high-technology industries are homogeneous both in terms of their locational tendencies and growth patterns. In this regard we have explored the degree to which these industries are in some way distinct and tested the assumption that certain areas have garnered new high-technology employment growth. In addition we have examined the degree to which high-technology industry concentrations, and changes in them over time, can be explained by characteristics of the labor force and metropolitan business climate.

In each phase of this research our basic hypothesis has been that these industries exhibit much greater complexity, diversity, and ambiguity in their growth performance and locational behavior, making generalizations more hazardous than sanguine policymakers and the business press would imply. For example, in simple growth terms, one-third of the 277 metropolitan areas, as designated in 1977, experienced net job loss in the 1972-77 period.

In the sections that follow we take up each of these issues in turn:

1. What is the nature and diversity among high-technology industries in both growth performance and locational tendencies?
2. Which metropolitan areas exhibit the greatest high-technology dependency and which have experienced the greatest rates of plant and job change?
3. What spatial factors appear to be most closely associated with these industries?

The Growth and Locational Diversity of High-Technology Industries

A major fault with the burgeoning literature on high-technology industries is its tendency to treat them as a rather homogeneous group. One of our fundamental hypotheses is that high-technology industries are exceptionally diverse in two ways. First, they vary widely in plant and job creation potential. Second, they display

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[*] This report was prepared by Amy K. Glasmeier, Peter G. Hall, and Ann R. Markusen, at the Institute for Urban and Regional Studies, University of California-Berkeley under contract with OTA. The development of the data base and the majority of the descriptive analysis was done under contract with the National Science Foundation, contract No. SES 82-08104.

[1] *Technology Innovation and Regional Economic Development: Census of State Government Initiatives for High-Technology Industrial Development—Background Paper* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-BP-STI-21, May 1983).

[2] Employment size categories were used to estimate employment for individual industries. No further analysis was performed using the size categories.

widely different locational patterns, both in degree of dispersion and in tendencies toward increasing dispersion over time. A related hypothesis—one that has prompted us to pursue a highly disaggregated data analysis—is that the constituent members of two- and three-digit high-technology industries are dramatically different. The documentation of these variations in growth and spatial tendencies has crucial implications for economic development and planning. If substantial variation does exist, then high-technology job creation strategies will have to be finely tuned to individual sectors.

Growth Rates

High-technology industries produced widely divergent employment growth rates over the mid-1970's (see table C-1). The best performers were sectors like Computers and Petroleum Refining, which created total net new jobs of 47,900 and 46,000 respectively. Smaller, innovative sectors in the Scientific Instruments and Measuring and Controlling Instruments fields posted even higher percentage job growth rates. For instance, the Fluid Meters industry expanded at the phenomenal rate of 80.68 percent. These extraordinary performances are what both policymakers and the press envision when they hanker after high-technology economic development.

What is less popularly understood is the degree to which growth in these sectors is in part countervailed by job and plant losses in other high-technology sectors. Among our set of 100 four-digit industries, a total of 34 actually declined in employment over the period, while another 8 grew by less than the national manufacturing average. Taken together, these relatively poor performers constituted 42 percent of our industrial set, accounting for 30 percent of total 1977 high-technology employment. Indeed, the better-than-average growth sectors had to create 167,802 gross additional jobs to ensure a net gain of 377,895 in all high-technology sectors.

Divergent growth rates are sometimes the product of substitution of new commodities for older ones. In some cases, these occur in quite different plants. For instance, the development of robotics has resulted in some job growth in computing equipment, electronics and even service sectors like computer software displacing some employment in machining sectors and other assembly-type production processes. In other cases, the substitutions are more closely related, even within three-digit categories. For instance, the growth of semiconductors is directly linked to job loss in electronic tubes and transistors, as the product of the former displaces that of the latter.[3]

Interindustry Patterns of Dispersion

Similarly, the degree of geographical concentration is quite distinct across high-technology sectors and varies almost as much within industrial groupings as across the entire set. In order to detect the variation among our 100 high-technology industries for both 1972 and 1977,[4] the index provides a measure of the degree of dispersion or concentration in each industry across all 3,140 counties in the United States for the given year. A value of zero implies total spatial dispersion, while a value of 8.16 implies total concentration of the industry in one county.[5] Entropy indexes were computed for both plants and employment. Comparing the 2 years gives us a clear indication of the tendencies toward further dispersion or concentration among high-technology sectors.

Individual high-technology industries show extraordinary degrees of dispersion across U.S. counties. The dispersion rankings differ slightly depending on whether incidence of plants or employees by number of counties, entropy index for plants, or entropy index for jobs, is used (see table C-2). In 1977, the most highly concentrated industry in terms of employment was Miscellaneous Missile and Space Vehicle Parts (SIC 3769). Its nearly 10,000 jobs, concentrated in just 31 counties, gave it an entropy index value of 6.22. A companion sector, Guided Missiles and Space Vehicles (SIC 3761), posted the highest concentration of plants, at 5.38, its 94,000 jobs located in just 21 counties. On the basis of absolute county incidence, the most highly concentrated industry was Tanks and Tank Components (SIC 3795), whose 12,000-plus jobs could be found in only 19, or less than 1 percent of all U.S. counties.[6]

The industry with the most highly dispersed employment in 1977 was Fertilizers (SIC 2875). Its 12,000 jobs were distributed across 469 counties. Its employment dispersion value was 2.65 and plant value was 2.08; both were the lowest in the set. On a county-by-county basis, Dies and Industrial Molds (SIC 3544) could be found in

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[3] As we shall see below, these distinctions are important because the location of semiconductors is quite different from that of the product it has replaced.

[4] The entropy index is calculated by the following formula:
where I(y) is the overall U.S. entropy index of spatial inequality for industry, i, y is the share of the r^{th} county of all U.S. employment in industry i R is the total number of counties in the United States (R = 3,140).

Since the log of zero is undefined, this equation deals with the numerous cases of counties with no employment by setting the expression to the right of the summation sign equal to zero, since the logged portion will in each case be multiplied by a zero and an undefined value times zero is zero.

The entropy index was first developed by Theil (1967) and has been used by locational researchers, primarily in Britain (Keeble, 1976: 25-30; Martin, 1972; Chisholm and Oeppen, 1973: 34-6).

[5] The absolute values of the indexes are less interesting than their comparative size across industries and changes in them over time. We would not expect all industries to be equally distributed across U.S. counties and not surprisingly, the most ubiquitous of the set was to be found in only 799 out of the 3,140 counties in 1977, while second place went to an industry found in 521 counties.

[6] An industry with the greatest incidence by number of counties can be less dispersed than others, as is the case here, when its plants and/or jobs remain heavily concentrated in only a few of those counties.

Table C-1.—High-Technology Industries Growth Performance, 1972-77

SIC	Industry name	1977 Number of jobs	1977 Number of plants	1972-77 Net new jobs	1972-77 Net new plants	Percent job change	Percent plant change
2812	Alkalies and chlorine	11,831	49	−1,500	1	−11.3	2.1
2813	Industrial gases	7,332	562	−2,100	59	−22.3	11.7
2816	Inorganic pigments	12,003	106	− 700	−8	−5.5	−7.0
2819	Industrial inorganic chemicals, n.e.c.[a]	78,192	564	15,000	180	23.3	46.9
2821	Plastic materials, syn. resins	57,111	397	2,400	74	4.4	22.9
2822	Synthetic rubber	11,538	63	−1,800	4	−13.5	6.8
2823	Cellulosic man-made fibers	16,224	25	−1,100	7	−6.3	38.9
2824	Syn. organic fibers, ex. cellul.	74,067	66	−4,200	5	−5.4	8.2
2831	Biological products	18,498	310	5,600	128	43.4	70.3
2833	Med. chem. botanical prod.	15,730	177	6,600	37	72.3	26.4
2834	Pharmaceutical preparations	126,445	756	14,400	0	12.9	0.0
2841	Soap, other detergents	32,621	638	600	3	1.9	0.5
2842	Spec. cleaning, polishing prep.	22,941	1,022	−3,000	−84	−11.6	−7.6
2843	Surface active finishing agents	6,851	175	−300	−3	−4.2	−1.7
2844	Perfumes, cosmetics, toilet prep.	50,775	693	2,700	0.48	5.6	7.4
2851	Paints, varnishes, lacquers, enamels	61,343	1,579	4,500	−19	7.9	−1.2
2861	Gum, wood chemicals	4,717	119	−1,100	−20	−18.9	−14.4
2865	Cyclic crudes, intermediates, dyes	35,499	191	7,500	17	26.7	9.8
2869	Industrial organic chemicals, n.e.c.	112,426	569	9,900	56	9.7	10.9
2873	Nitrogenous fertilizers	12,443	152	2,700	79	27.7	108.2
2874	Phosphatic fertilizers	15,704	91	−500	−54	−3.1	−37.2
2875	Fertilizers, mixing only	12,401	673	1,000	46	8.8	7.3
2879	Pesticides, agr. chem. n.e.c.	15,131	409	2,800	21	22.8	5.4
2891	Adhesives, sealants	16,647	573	1,800	110	12.1	23.8
2892	Explosives	11,546	97	−6,300	5	−35.3	5.4
2893	Printing ink	10,106	446	500	40	5.2	9.9
2895	Carbon black	2,601	31	−400	−6	−13.3	−16.2
2899	Chem., chem. prep., n.e.c.	35,382	1,639	−1,800	34	−4.8	2.1
2911	Petroleum refining	102,398	349	46,000	26	80.1	8.0
3031	Reclaimed rubber	1,008	21	0	1	0.0	5.0
3482	Small arms ammunition	12,199	65	−3,600	3	−22.8	4.8
3483	Ammunition, except small arms, n.e.c.	20,589	81	−36,000	−14	−63.6	−14.7
3484	Small arms	17,495	112	1,400	30	8.7	36.6
3489	Ordnance, accessories, n.e.c.	19,042	89	−1,000	13	−4.9	17.1
3511	Steam, gas, hydraulic turbines	40,971	83	−5,400	8	−11.6	10.7
3519	Internal combustion engines, n.e.c.	88,804	232	18,900	54	27.0	30.3
3531	Construction mach., equipt.	155,129	922	21,500	175	16.0	23.4
3532	Mining mach., equipt	31,312	344	10,100	104	47.4	43.3
3533	Oil field mach., equipt.	58,469	478	22,700	163	63.4	51.7
3534	Elevators, moving stairways	10,214	152	−4,800	−2	−32.0	−1.3
3535	Conveyors, conveying equipt	32,926	616	5,700	124	20.9	25.2
3536	Hoists, ind. cranes, monorail syst.	15,820	242	−500	54	−3.1	28.7
3537	Ind., trucks, tractors, trailers, stackers	28,383	475	3,000	95	11.7	25.0
3541	Mach. tools, metal cutting types	59,432	919	7,000	25	13.3	2.8
3542	Mach. tools, metal forming types	23,154	429	−400	46	−1.7	12.0
3544	Spec. dyes, die sets, jigs fix., ind. molds	106,175	7,152	7,800	536	7.9	8.1
3545	Mach. tool accessories, measur. devices	54,177	1,412	7,400	181	15.8	14.7
3546	Power driven hand tools	27,667	124	4,600	36	19.9	40.9
3547	Rolling mill machine equipment	8,529	63	−2,500	16	−22.7	34.0
3549	Metalworking mach., n.e.c.	19,086	534	5,800	141	43.7	35.9
3561	Pumps, pumping equipment	63,025	613	7,500	54	13.5	9.7
3562	Ball, roller bearings	50,286	149	−300	14	0.6	10.4
3563	Air, gas compressors	31,916	175	9,100	91	39.9	108.3
3564	Blowers, exhaust, ventil. fans	28,415	482	4,500	86	18.9	21.7
3565	Industrial patterns	9,352	1,002	800	−19	9.3	−1.8
3566	Speed changers, ind., high drives, gears	24,572	327	−200	−19	−0.8	−5.5
3567	Ind. process furnaces, ovens	16,260	327	1,600	61	10.9	22.9
3568	Mech. power transmission equip. n.e.c.	32,564	226	4,800	71	17.3	45.8
3569	General ind. mach. equipt. n.e.c.	58,621	1,646	20,500	746	53.8	82.9
3573	Electronic computer equipment	192,510	932	47,900	332	33.1	55.3
3574	Calc. acc. mach. ex. elec. compt. equipt.	15,474	64	−5,400	−15	−25.9	−19.0

Table C-1.—High-Technology Industries Growth Performance, 1972-77 (continued)

SIC	Industry name	1977 Number of jobs	1977 Number of plants	1972-77 Net new jobs	1972-77 Net new plants	Percent job change	Percent plant change
3576	Scales, balances, ex. lab.	6,738	103	400	6	6.3	6.2
3579	Office machines, n.e.c.	42,398	218	7,900	3	22.9	1.4
3612	Power, distr. special transformers	43,360	279	−3,500	63	−7.5	29.2
3613	Switchgear, switchboard apparatus	72,211	668	2,800	100	4.0	17.6
3621	Motors, generators	96,951	447	6,600	22	7.3	5.2
3622	Industrial controls	56,408	726	4,100	143	7.8	24.5
3623	Welding apparatus, electric	17,409	176	2,000	10	13.0	6.0
3624	Carbon, graphite products	12,086	74	800	2	7.1	2.8
3629	Elec. ind. apparatus, n.e.c.	16,490	223	4,300	35	35.3	18.6
3651	Radio, TV receiv. sets, ex. comm. types	74,639	581	−11,900	211	−13.8	57.0
3652	Phono records, pre-recorded MagTape	23,131	709	2,800	142	13.7	25.0
3661	Telephone, telegraph apparatus	124,345	264	−10,000	62	−7.4	30.7
3662	Radio TV transmit, signal, detect. equipt.	333,006	2,121	14,900	350	4.7	19.8
3671	Cathode ray tubes, n.e.c.	36,808	146	−9,202	−8	−20.0	−5.2
3674	Semiconductors, related devices	114,011	545	16,400	219	16.8	67.2
3675	Electronic capacitors	28,647	118	1,300	5	4.8	4.4
3676	Resistors for electronic app.	24,918	101	800	5	3.3	5.2
3677	Resistors, electric apparatus	22,424	294	−3,500	54	−13.5	22.5
3678	Connectors, electronic appls.	26,020	133	7,900	42	43.6	46.2
3679	Electronic components, n.e.c.	125,998	3,118	25,400	1,276	25.2	69.3
3721	Aircraft	222,805	176	−9,100	8	−3.9	4.8
3724	Aircraft engines, parts	106,222	269	1,400	37	1.3	15.9
3728	Aircraft parts, auxiliary equipt., n.e.c.	101,900	728	−200	34	−0.2	4.9
3743	Railroad equipt.	56,396	201	5,500	38	10.8	23.3
3761	Guided missiles, space vehicles	93,933	40	−24,400	−29	−20.6	−42.0
3764	Guided missiles, space veh. propul.units	17,011	26	−2,200	−3	−11.4	−10.3
3769	Guided missiles, space veh. parts n.e.c.	10,189	42	−13,700	−6	−57.3	−12.5
3795	Tanks, tank components	12,122	24	6,500	2	115.6	9.1
3811	Eng., lab., scientific, research inst.	42,178	786	5,697	47	15.6	6.4
3822	Auto., controls reg. resid., comm. env. appl.	39,076	201	8,300	70	27.0	53.4
3823	Ind. instr. measure, display	46,480	426	9,900	239	27.0	127.8
3824	Fluid meters, counting devices	16,032	111	7,100	50	79.5	82.0
3825	Instr. measuring, testing elec. elec. sigs.	66,622	671	11,800	26	21.5	4.0
3829	Measuring, controlling devices, n.e.c.	32,175	670	7,700	77	31.5	13.0
3832	Optical instru., lenses	29,883	545	11,200	51	59.5	10.3
3841	Surgical, medical inst. apparatus	43,206	651	8,700	145	25.2	28.7
3842	Orthopedic, prosthetic, surgical appl.	53,967	1,154	10,000	284	21.3	32.6
3843	Dental equipt., supplies	16,673	550	3,900	121	30.5	28.2
3861	Photographic equipt., supplies	111,568	780	15,700	156	16.4	25.0

[a] n.e.c.—not elsewhere classified.

SOURCE: Office of Technology Assessment.

799 (or 25 percent) counties, and Miscellaneous Electronic Components (SIC 3679) in 521 (or 17 percent). However, in both these sectors the distributions of plants and jobs were highly skewed among these few counties, so that they exhibited less real dispersion with the entropy index than did Fertilizers.

Several generalizations can be made about factors causing this wide range of spatial behavior. First, there appears to be little relationship between the size of an industry and its tendency to disperse. Some very large employers are highly concentrated, while other sectors, with only modest national levels of employment, are quite dispersed. Scale economies within sectors probably play a much greater role in the tendency for some to concentrate, irrespective of total industry size.

Second, industries appear to concentrate or disperse by type of product, major customer and resource dependency. For instance, two types of industries are prominent among the concentrators. Defense and space-oriented high-technology manufacturers are extraordinarily concentrated. Of the 18 sectors with job entropy values above 5.0 in 1977, eight produce weapons, tanks, spacecraft, airplanes and related parts. It is difficult not to draw the conclusion that military and space spending patterns and procurement practices have been a major contributor to the spatial concentration of an important segment of high-technology sectors in a small number of counties.

A quite different set of industries which appear to be highly resource oriented are also heavily concentrated spatially. These sectors account for another seven of the

Table C-2.—Dispersion Indexes for High-Technology Industries

SIC	Industry name	1972 dispersion indexes for Plants	1972 dispersion indexes for Employees	1977 dispersion indexes for Plants	1977 dispersion indexes for Employees
2812	Alkalies and chlorine	4.3	5.1	4.5	5.2
2813	Industrial gases	2.7	3.2	2.6	3.1
2816	Inorganic pigments	3.9	4.7	3.9	4.5
2819	Industrial inorganic chemicals, n.e.c.[a]	2.8	3.7	2.6	3.7
2821	Plastic materials, synthetic resins	3.2	3.8	3.1	3.6
2822	Synthetic rubber	4.5	5.6	4.3	5.6
2823	Cellulosic manmade fibers	5.2	5.7	4.8	5.9
2824	Synthetic organic fibers, except cellulose	4.1	4.6	3.9	4.4
2831	Biological products	3.5	4.7	3.1	4.2
2833	Medical chemical, botanical products	4.0	5.1	3.6	4.8
2834	Pharmaceutical preparations	3.2	4.0	3.1	3.9
2841	Soap, other detergents	3.3	4.1	3.3	4.0
2842	Special cleaning, polishing preparations	3.0	3.8	3.0	3.7
2843	Surface active finishing agents	4.0	4.4	4.0	4.4
2844	Perfumes, cosmetics, toilet preparations	3.8	4.3	3.7	4.3
2851	Paints, varnishes, lacquers, enamels	3.1	3.6	2.9	3.4
2861	Gum, wood chemicals	3.5	4.8	3.7	4.5
2865	Cyclic crudes, intermediates, dyes	3.7	4.2	3.6	4.3
2869	Industrial organic chemicals, n.e.c.	3.0	3.9	3.0	3.8
2873	Nitrogenous fertilizers	3.9	4.3	3.3	4.0
2874	Phosphatic fertilizers	3.5	4.3	3.9	4.9
2875	Fertilizers, mixing only	2.1	2.7	2.1	2.7
2879	Pesticides, agricultural chemicals, n.e.c.	2.8	3.9	2.8	4.0
2891	Adhesives, sealants	3.5	3.9	3.3	3.7
2892	Explosives	3.9	5.0	3.8	4.7
2893	Printing ink	3.8	4.2	3.6	4.1
2895	Carbon black	4.8	5.2	4.9	5.1
2899	Chemicals, chemical preparations, n.e.c.	2.8	3.3	2.6	3.1
2911	Petroleum refining	3.1	4.0	3.1	4.0
3031	Reclaimed rubber	5.3	6.1	5.1	6.0
3482	Small arms ammunition	4.2	5.7	4.2	5.8
3483	Ammunition, except small arms, n.e.c.	4.0	4.6	3.9	4.8
3484	Small arms	4.3	5.5	4.1	5.4
3489	Ordnance, accessories, n.e.c.	4.0	5.4	4.1	5.3
3511	Steam, gas, hydraulic turbines	4.1	5.2	4.0	5.2
3519	Internal combustion engines, n.e.c.	3.7	4.5	3.5	4.5
3531	Construction machine equipment	2.5	3.6	2.4	3.5
3532	Mining machinery, equipment	3.2	4.1	3.1	3.9
3533	Oil field machinery, equipment	4.5	5.5	4.2	5.3
3534	Elevators, moving stairways	3.8	4.6	3.7	4.4
3535	Conveyors, conveying equipment	3.0	3.6	2.8	3.3
3536	Hoists, industrial cranes, monorail system	3.5	4.6	3.3	4.0
3537	Industrial trucks, tractors, trailers, stackers	2.9	4.2	2.9	4.0
3541	Machine tools, metal cutting types	3.5	4.2	3.3	4.1
3542	Machine tools, metal forming types	3.6	4.3	3.3	4.2
3544	Special dyes, die sets, jigs fix., industrial molds	2.9	3.2	2.8	3.1
3545	Machine tool accessories, measuring devices	3.5	3.9	3.3	3.8
3546	Power driven hand tools	4.3	4.9	3.8	4.6
3547	Rolling mill machinery, equipment	4.6	5.6	4.5	5.4
3549	Metalworking machinery, n.e.c.	3.4	3.8	3.0	3.5
3561	Pumps, pumping equipment	3.0	3.5	2.9	3.5
3562	Ball, roller bearings	3.8	4.5	3.6	4.3
3563	Air, gas compressors	4.1	4.9	3.7	4.5
3564	Blowers, exhaust, ventilation fans	3.2	3.8	3.0	3.5
3565	Industrial patterns	3.1	3.5	3.0	3.4
3566	Speed changers, industrial high drives, gears	3.6	4.5	3.5	4.3
3567	Industrial process furnaces, ovens	3.7	4.3	3.6	4.1
3568	Machine power transmission equipment, n.e.c.	3.6	4.3	3.3	4.0
3569	General industrial machinery equipment, n.e.c.	3.0	3.4	2.7	3.0
3573	Electronic computing equipment	3.8	4.3	3.7	4.1

Table C-2.—Dispersion Indexes for High-Technology Industries (continued)

SIC	Industry name	1972 dispersion indexes for Plants	1972 dispersion indexes for Employees	1977 dispersion indexes for Plants	1977 dispersion indexes for Employees
3574	Calculating, accounting machines except elec. computing equip.	4.2	5.4	4.4	5.3
3576	Scales, balances, except laboratory	4.1	5.1	3.9	4.7
3579	Office machines, n.e.c.	3.7	4.8	3.7	4.9
3612	Power, distr. special transformers	3.3	4.2	3.2	4.0
3613	Switchgear, switchboard apparatus	3.2	4.0	3.0	3.7
3621	Motors, generators	3.1	3.4	3.0	3.3
3622	Industrial controls	3.2	4.3	3.1	3.9
3623	Welding apparatus, electric	4.0	4.6	3.8	4.7
3624	Carbon, graphite products	4.3	5.4	4.4	5.3
3629	Electrical industrial apparatus, n.e.c.	3.8	4.4	3.6	4.3
3651	Radio, TV receiver sets, except comm. types	3.7	4.6	3.3	4.4
3652	Phono records, pre-recorded MagTape	4.4	4.7	4.3	4.7
3661	Telephone, telegraph apparatus	3.6	4.4	3.6	4.4
3662	Radio/TV transmitting, signal detection equipment	3.1	3.7	3.0	3.6
3671	Cathode ray tubes, n.e.c.	4.9	6.0	3.8	4.9
3674	Semiconductors, related devices	3.9	4.7	3.7	4.8
3675	Electronic capacitors	4.0	4.2	4.2	4.4
3677	Resistors, electric apparatus	3.7	3.8	3.6	3.9
3678	Connectors, electronic appliances	4.5	5.0	4.2	4.7
3679	Electronic components, n.e.c.	3.1	3.4	3.0	3.4
3721	Aircraft	3.9	5.2	4.0	5.1
3724	Aircraft engines, engine parts	4.0	4.9	3.9	4.8
3728	Aircraft parts, auxillary equipment, n.e.c.	4.2	4.5	4.0	4.6
3743	Railroad equipment	3.8	4.7	3.5	4.7
3761	Guided missiles, space vehicles	4.9	5.6	5.4	5.7
3674	Guided missiles, space vehicles, propulsion units	5.0	5.5	5.2	5.6
3769	Guided missiles, space vehicles parts, n.e.c.	4.9	5.5	4.9	6.2
3795	Tanks, tank components	5.3	6.4	5.2	6.1
3811	Engineering, laboratory, scientific research institutions	3.3	3.8	3.1	3.8
3822	Auto. controls for regulating residential commercial environment	3.8	4.9	3.5	4.7
3823	Industrial instr., measure, display	4.0	4.9	3.5	4.4
3824	Fluid meters, counting devices	4.3	4.9	3.8	4.8
3825	Instr. measuring, testing elec. elec. sigs.	3.4	4.1	3.3	4.0
3829	Measuring, controlling devices, n.e.c.	3.3	4.4	3.2	4.3
3832	Optical instruments, lenses	3.6	4.4	3.4	4.2
3841	Surgical, medical instruments, apparatus	3.3	3.8	3.2	3.7
3842	Orthopedic, prosthetic, surgical appliances	2.9	3.6	2.7	3.5
3843	Dental equipment, suplies	3.6	4.2	3.3	4.1
3861	Photographic equipment, supplies	3.7	5.1	3.5	4.8

[a] n.e.c.—not elsewhere classified.

NOTE: With this data, an index of 8.2 implies total concentration, an index of zero implies total dispersion.

SOURCE: Glasmeier, et al.

top 18 highly concentrated industries and run the gamut from oil field machinery to raw materials-related commodities like carbon products, alkalies and chlorine, synthetic rubber, and manmade fibers. In some cases, such as oil field machinery, it is *demand* from a resource sector that has drawn the industry to a small set of locations. In others, it is the *supply* of a raw material or a primary processing sector input which seems to account for its concentration.

In both these two types of sectors, the "age" of the industry appears to have less to do with its locational concentration than its product type and client relationships. In addition, plants in these industries are often quite large scale in nature, either because their product is immense (aircraft, missiles) or because continuous-process technology facilitates very large economies of scale. Therefore, a few big plants serve most of the market.

At the other end of the spectrum, a set of relatively mature, producer goods sectors dominate the rankings. Many of these highly dispersed sectors produce heavy or bulky material inputs for a relatively dispersed set of industrial or agricultural consumers (fertilizers, paints, chemicals). Others produce custom-made equipment for relatively dispersed industrial users (dyes, motors, electronic components, conveyors). In both instances, market orientation seems to be drawing the industry.

In the middle range lie many of those high-technology industries which are most innovative and fastest growing. Computers, semiconductors, biological products, measuring devices, industrial controls, optical instruments, and machine tools are all only moderately dispersed compared to the average for all high-technology industries. This may be a function of youth and the need to cluster in certain places in order to watch competitors, draw upon secondary business services and a skilled labor pool, and be close to the centers of action. Yet it is still true that sectors like semiconductors could be found in a total of 182 counties in 1977, and computers in 203, suggesting that decentralization of at least some innovative high-technology production activities was fairly advanced.

A final type of interindustry variation is the extent to which the counties hosting high-technology plants and jobs in a particular sector are closely associated geographically. One measure of this is the degree to which county incidence corresponds to the Standard Metropolitan Statistical Area (SMSA) incidence. (Of course, this comparison is complicated by the fact that some SMSAs have more counties on average than others.) The second column in table C-2 shows the number of SMSAs in which each industry is represented. The lowest is for Carbon Black, which was produced in only 10 SMSAs in 1977. This same sector ranked 6th in county concentrations; the implication is that the counties in which it is found are more apt to be included within the same SMSAs in contrast to other highly concentrated sectors found in few counties but proportionately more SMSAs. The industry to be found in the most SMSAs is Dyes and Industrial Molds (SIC 3544), which occurred in 209 SMSAs in 1977. The defense and space-related sectors discussed above showed a high degree of concentration in a few metropolitan areas: Guided Missiles and Space Vehicles and Parts (SICs 3761 and 1764) were found in only 18 SMSAs, while Tanks (SIC 3795) are produced in only 12.

Intraindustry Patterns of Dispersion

Sectors normally grouped together in two- and three-digit industries showed quite dramatic variation among them in degrees and rates of dispersion. There were very few three-digit industries whose constituent members had similar entropy index values. The least variation was to be found in two groups. First, relatively similar rates of quite high concentration were found in the space and defense-related sectors: Ordnance (SIC 348), Aircraft and Parts (SIC 372), and Missiles (376). Second, the Measuring and Control Devices category (SIC 382) had relatively similar dispersion patterns among its five component subsectors. However, other types of scientific instrument subsectors had quite disparate patterns.

A few examples will illustrate the extent of these variations within broad groupings. Within Industrial Inorganic Chemicals (SIC 281) subsectors, Alkalies and Chlorine were highly concentrated while Industrial Gases were quite dispersed; of our 100 sectors, the former ranked 84th in degree of job dispersion while the latter was 2d. Within Metal Working Machinery (SIC 354), Dyes and Industrial Molds was the third most dispersed high-technology sector in our set, while Rolling Mill Equipment was 91st. Among Electronics sectors, Semiconductors ranked 78th while Miscellaneous Electronic Components ranked 6th. The point is that one four-digit sector is often very unlike another sharing the same umbrella designation.

Changes in Patterns of Dispersion, 1972-77

Over the period studied, there has been an overwhelming tendency for both plants and employment to disperse across U.S. counties. In only 14 of our 100 sectors did the plant entropy index increase, indicating cases of greater concentration. The job entropy index increased in 22, or about one in five, sectors. If anything, the degree of differentiation among industries increased. Almost universally, dispersed sectors became even more dispersed, while the highly concentrated ones were as apt to intensify their plant concentrations as they were to disperse.

More specifically, the vast majority of sectors which did increase their plant concentrations fall into the two groups mentioned above—military-related sectors and bulk materials processors. Here, the forces originally working toward concentration seem to be continuing that trend. This is particularly striking in the military equipment and supplies case, where tanks, small arms ammunition, guided missiles, space vehicles and parts, aircraft, and aircraft parts were found among the minority of sectors that intensified either plant or job concentrations.

Product cycles theories suggest that the more innovative and fast-growing sectors tend to cluster initially around a few sites of entrepreneurial initiative and specialized labor pools. Once the product is standardized and market penetration becomes a dominant business strategy, jobs will tend to disperse toward users. Once markets are saturated and competition becomes intense, production jobs may reconcentrate in the lowest cost locations, far from the original centers of production.[7] Although our data base does not permit us to test these hypotheses in the appropriate longitudinal form, a number of cautious insights can be gleaned from the comparison of dispersion tendencies over this short period.

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[7] For a full development of this evolutionary model and its spatial implications, see Ann R. Markusen, "Profit Cycles, Obligopoly and Regional Transformation," Working Paper No. 397, Institute of Urban and Regional Development, University of California, Berkeley, January 1983.

Generally, the more innovative, growing high-technology sectors tended to disperse along with other sectors. However, variations within these groups appear to be greater than for other groups. In a few cases, employment continued to concentrate at existing sites, supporting a product cycle interpretation which hypothesizes concentration in initial stages. Semiconductors is an outstanding example. While plants dispersed in the 1970's, and the industry increased its incidence from 120 to 182 counties, jobs actually became more concentrated spatially. Several other electronic sectors also became more concentrated (resistors, telephone equipment). Most other rapid-growth sectors showed a modest tendency toward decentralization from original growth centers.

The only other sectors which showed a tendency to increase locational concentration rather than to disperse were a set of relatively highly automated process sectors, whose initial locations were already relatively dispersed. Examples are industrial inorganic chemicals, pesticides and agricultural chemicals, cosmetics, phosphatic fertilizers, and finishing agents. The tendency to reconcentrate here is often a result of rationalization—selective plant closings and relatively larger scale plants in new or existing locations.

A Summary of Industry Growth and Locational Diversity Findings

The extraordinary degree of diversity across and among industries in growth and locational tendencies vindicates our hypotheses about large differences and supports our choice of four-digit SIC categories as appropriate for spatial analysis. Growth rates range from the phenomenal (110 percent) to the negative. While some high-technology sectors are found in as few as 10 metropolitan areas, others—often with lower numbers of total employees—can be found in more than 100—even 200—SMSAs. Product type, client characteristics, and production process seem to be stronger determinants of comparative dispersion patterns than maturity of the industry, national employment size, or three-digit SIC grouping. (The lack of similar entropy values for industries in the given years is not an adequate test of a product lifecycle hypothesis, which argues that jobs and plants in any one industry disperse over time; cross-sectional comparisons of industries at different degrees of maturity are not a good proxy for a longitudinal comparison.)

Most high-technology sectors did disperse over the 1970's period studied, even when their growth rates were modest. Exceptions (i.e., sectors which became more concentrated by 1977 than in 1972) were in military and space-related manufacturing, sectors with highly automated production processes, and occasionally, highly innovative sectors such as some types of electronics. In addition, a few declining high-technology sectors became more spatially concentrated as a result of spatially selective rationalization.

The Range of High-Technology Presence Across Metropolitan Areas

A central hypothesis of our work on high-technology industries is that—whether measured by plant and job incidence, growth rates, or significance as a portion of the economic base of individual regional or metropolitan economies—they are quite complex and diverse from place to place. The most commonly cited example of a fast-growing, "high-tech" center is Silicon Valley, coterminant with the San Jose SMSA. In fact, our research indicates that Silicon Valley is an extraordinary place, the exception rather than the rule by almost any measure. Generalizations about places that lack or have experienced negative growth rates in high-technology plants and jobs are also difficult. New York did turn out to be one of the most dramatic losers, but others in this position were surprises. But in both growth and decline cases, some definite answers about the size, region, and type of SMSA most likely to lead the group can be given.

To explore our contentions about complexity, we developed profiles of the 10 highest and 10 lowest metropolitan performers. We used the 264 SMSAs as defined in 1977[8] for this analysis, because a county-by-county analysis was beyond our present resources and because metropolitan comparisons would convey more about the patterns of high-technology spatial change to the lay reader. Over 80 percent of all high-technology employment was located in these metros. Five measures of high-technology industry incidence were computed: the ratio of high-technology to areawide employment in 1977, the percent change in plants, the percent change in employment, the net absolute change in numbers of plants from 1972 to 1977, and the net change in absolute numbers of jobs for the same period. While we computed these values for all SMSAs, we have chosen to analyze comparatively only those on the tail end of the distribution, believing that the extremes give the best shorthand picture of the range of high-technology experience.

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[8] Although there were 277 SMSAs in 1977, six were not part of this analysis. The SMSAs in Puerto Rico were not included as well as Burlington, VT, and Cheyenne, WY. These latter two were excluded because metropolitan socioeconomic data were not available for them. The remaining six were New England SMSAs which were collapsed into New England County Metropolitan Areas.

New England States present a particular problem when trying to aggregate up from counties to SMSAs. In a number of cases, Northeastern SMSAs are composed of noncontiguous counties, cities, and townships. To simplify spatial analysis and aggregation of data on places, New England county metropolitan areas were instituted. This research uses the Bureau of Economic Analysis 1977 definition of NECMAs. These include: Boston, MA, Bridgeport, CT, Hartford, CT, New London, CT, Worcester, MA, and Fall River, MA.

Before looking at each set of leading gainers and losers, it is worth summarizing briefly our findings on the basis of size, region, and type of metropolitan area. For the latter, we have grouped the leaders in three categories: 1) big-city SMSAs (those which focus on one of the traditional top 20 central cities); 2) adjacent, or suburban, SMSAs (those which are contiguous to one of the previous class); and 3) independent SMSAs (those which fall into neither of the previous two classes).

First of all, we found that big-city SMSAs dominate the rankings of metros with the greatest absolute job loss. Paradoxically, the same type of SMSA dominates the rankings for absolute plant gain. As a result, we found anomalies such as the fact that the Los Angeles SMSA was ranked among the top 10 job losers but was also found among the top 10 plant gainers.

Adjacent, or suburban, SMSAs along with the newer big-city SMSAs, are relatively more prominent in the category of absolute job gain. This implies that these types of SMSAs, like Anaheim and San Jose, CA, and Worcester, MA, are attracting bigger size plants than older big-city SMSAs. But in terms of absolute plant losses, neither big-city nor suburban SMSAs make much of a showing among the leading ranks. Big numbers of plant closings are surprisingly concentrated in small and medium-sized independent SMSAs like Lansing, MI, Johnstown, PA, and Muncie, IN.

But if big-city SMSAs are most prominent among the places that account for the greatest absolute gains and losses, they do not dominate the rankings of percentage change. Here, small to medium-sized places are remarkably strong. For instance, in the percent gain in employment, not one big-city SMSA shows up in the top 10 and only one, Santa Rosa, CA, is suburban. Among leading percent job losers, places like Eau Claire, WI, Decatur, IL, and Gadsden, FL, crowd out larger places. Only Miami among the big-city SMSAs shows up with a leading net job decline rate. The implication is that high-technology gains and losses are proportionately much more dramatic and perhaps, traumatic, for these medium-sized, mostly detached SMSAs.

What is also quite clear is that the most high-technology dependent places, i.e. those with the greatest percent of their labor force in high-technology industries, are also the smaller and medium-sized SMSAs. Only San Jose, CA, among major metro areas shows up as having a high ratio. The other top places are not apt to be those people think of as high-technology dominated. Furthermore, the leading high technology dependent centers are more apt to be found in the Midwest and South than in other parts of the country.

Regionally, other anomalies turn up. Texas, which is often thought of as a high-technology State, has three of the least high-technology dependent SMSAs in the country—i.e., Killeen, McAllen, and Laredo. Frostbelt locations do account for the worst absolute plant losses, but Sunbelt SMSAs like Los Angeles and Miami are prominent among the biggest job losers. Furthermore, some Frostbelt big-city SMSAs are leading percent plant gainers, like Minneapolis, Chicago, and Detroit. Southern and Midwestern SMSAs are more prominent among percent job losers than Northeastern SMSAs. Nor did States host high-technology growth evenly across their metro areas. All of these points underscore the degree to which spatial generalization is a hazardous task.

A final summary point is that the presence of high-technology activity does not ensure an area an expansionary future. Over the 1972-77 period, fully one-third of the 277 metro areas in the U.S. lost jobs. On average, these job losses were larger in magnitude than were average job gains.

High-Technology Employment Ratio

High-Technology Dependence: The Top Ten.—The high-technology employment ratio consists of total high-technology employment divided by the metro labor force for each metro area. It is a measure of relative high-technology industry dependence across all metropolitan areas. The higher the ratio, the more prominent high-technology jobs are in the a real employment base. Given popular impressions of high-technology leaders, we expected to find places like Boston, San Jose, and several Texas SMSAs high on this list. And, we expected most to be found in Sunbelt, particularly Southwest, locations.

In fact, the places with highest and lowest high-technology dependence are a highly geographically diverse group, as table C-3 shows. Among the top 10, only San Jose fits the popular notion of a high-technology center. Knowledge of the metropolitan industrial base and the degree of military-government influence help explain this diverse group of 10. For example, the extraordinary high-technology dependence of Melbourne-Titusville, FL, is largely due to Cape Canaveral and the NASA Kennedy Space Center, as well as other nonspace, military-related facilities located there. In another case, Wichita, KS, is a small aircraft production center as well as the location of Boeing and Lockheed's plane storage and maintenance center. This diverse group of metro areas are not predominantly concentrated in one region at the expense of another. The Midwest and South account for six of the top 10 locations. Nor were the least high-technology dependent places a homogeneous group.

High-Technology Dependence: The Bottom Ten.—The 10 metro areas with the lowest high-technology ratio were all Sunbelt and non-Northeastern locations. Several, like Grand Forks, ND, and Great Falls,

Table C-3.—SMSAs With the Highest and Lowest High-Technology Ratio, 1977

Highest percent		Lowest percent	
Rockford, IL	0.19617	Killeen, TX	0.00043
Melbourne-Titusville, FL	0.17956	Columbia, MO	0.00054
Wichita, KS	0.17670	Grand Forks, ND-MN	0.00081
San Jose, CA	0.17355	Pueblo, CO	0.00102
Binghamton, NY	0.15219	Anchorage, AK	0.00118
Lake Charles, LA	0.14670	Clarksville, TN-KY	0.00173
Cedar Rapids, IA	0.14600	Honolulu, HI	0.00228
Bloomington, IN	0.12915	Great Falls, MT	0.00328
Johnson City, TN-WV	0.12817	McAllen Pharr, TX	0.00385
Longview, TX	0.12702	Laredo, TX	0.00398
Median	0.04364		

SOURCE: Office of Technology Assessment.

MT, are predominantly agricultural centers. Anchorage's economy is wrapped up with natural resource extraction-related activities. Honolulu, HI, is a combined trade, administration, and tourist center, while Columbia, MO, is primarily a big university town. These latter two cases demonstrate that educational and State government centers do not necessarily ensure an even modest dose of high-technology employment. Whereas no State was represented more than once in the top 10 metro areas, Texas has three of the 10 metro areas with the lowest high-technology ratio.

Percentage Changes in Plants, 1972-77

Rankings by percentage change in plants also yield an unexpected array of high-technology locations. Medium-sized noncentral city metros predominate in both top and bottom rankings. Regional incidence is somewhat skewed on a Sunbelt-Frostbelt basis. table C-4 presents the top 10 gainers and losers of high-technology plants in the mid-1970's.

Percent Plant Gainers: The Top Ten.—A set of non-Northeastern medium-sized metros dominates the percent plant winner category. The use of percentage changes highlight places with small high-technology bases in the first period. With the exception of Oxnard, CA, which had 55 plants in 1972 and added 63 more by 1977, the top 10 locations all began with bases of less than 23. As a group, these areas with the highest percentage increase in plants are non-big-city SMSAs. Several, such as Oxnard and Santa Cruz, CA, are adjacent to other large metro areas such as Los Angeles and San Jose. Half are in the Sunbelt, while the remainder are predominantly Midwestern.

Percent Plant Losers: The Bottom Ten.—The metro areas with the greatest percentage loss in plants present a striking contrast to the plant winners. Eight of the 10 are older Midwestern and Northeastern industrial metropolitan areas. Again, as with the winners, the relatively small economic base of these areas explains the significance of their losses. Four of the 10 locations had less than 20 plants in 1972. A loss of two or three plants may register as a 10- to 20-percent decline. All the top percent plant losers are thus medium-sized metro areas outside the urban core. As we shall see below, none of these percent plant losers was among the top 10 in percentage employment loss. This implies that the average plant closing was smaller than in other, larger, metropolitan areas.

Table C-4.—The Top Ten Gainers and Losers of High-Technology Percent Plants Change, 1972-77

Winners	Percent change	Number of plants		Losers	Percent change	Number of plants	
		1972	1977			1972	1977
Lawton, OK	600.00	1	6	Elmira, NY	−34.62	26	17
St. Cloud, MN	214.29	7	15	Anchorage, AK	−20.00	10	8
Laredo, TX	150.00	2	3	Pensacola, FL	−20.00	15	12
Santa Cruz, CA	137.50	16	22	Muncie, IN	−18.00	50	41
Champaign-Urbana, IL	118.18	11	13	Kokomo, IN	−17.86	28	23
Oxnard, CA	114.55	55	63	Johnstown, PA	16.13	31	26
Fort Myers, FL	110.00	10	11	Altoona, PA	−14.29	14	12
Billings, MT	100.00	7	7	Terra Haute, IN	14.29	35	30
Cedar Rapids, IA	100.00	23	23	Williamsport, PA	14.29	21	18
Panama City, FL	100.00	3	3	Pine Bluff, AR	−12.50	8	7
Median	18.18		11				

SOURCE: Office of Technology Assessment.

Percentage Changes in Employment

Percent Job Growth: The Top Ten.—SMSAs with the greatest percentage growth in employment were generally suburban, medium-sized metros rather than either smaller non-adjacent, non-big-city associated places or large central city metros. All of the 10 areas with the greatest percentage increase in high-technology employment are located outside the industrial Northeast (see table C-5). This group encompasses sites of both new high-technology growth as well as expansion in existing locations. But percent gain does not necessarily imply the greatest number of new jobs. As we shall see below, with the exception of Lakeland, FL, none of the top percent gainers scored in the top 10 in terms of absolute job gain. However, unlike plant gainers, a metro did not have to be small in order to post healthy high-technology job growth rates. Santa Rosa, CA, Lakeland, FL, Lubbock, TX, and Savannah, GA, all had big high-technology job bases in the first period. The most significant local growth rates in high-technology employment did not occur in the smaller locations but rather in suburban medium-size metro areas.

Percent Job Loss: The Bottom Ten.—Approximately one-third, or 86, metropolitan areas had net high-technology employment losses between 1972 and 1977. The net employment losers are relatively less geographically concentrated than job gainers: four of the 10 were in the South and four were in the Midwest. As we shall see below, three of the top 10 losers were also among the top 10 losers in absolute employment: Decatur, IL, Miami, FL, and Parksburg, WV-OH. Rankings by percentage change underplay the extent of absolute job loss taking place in a number of locations. For example, Miami lost almost half its high-technology employment base or 8,000 jobs, during the 5-year period. But its percent loss was smaller than that of Brandenton, FL, which lost a net 310 jobs in the same period.

Net Changes in High-Technology Employment

Absolute Job Gain: The Top Ten.—A total of 180 SMSAs, or about two-thirds, had absolute increases in high-technology employment. The median increase was 248 employees. As seen in table C-6, the ensemble of the top 10 metro areas with the greatest absolute change in high-technology employment comes closest to resembling the popular notion of high-technology centers. The top five ranking is predictable with San Jose (Silicon Valley) leading the group, followed by Anaheim, Houston, San Diego, and Boston. The remaining locations present two surprises: Oklahoma City, OK, and Lakeland, FL. Regionally, two Boston-area SMSAs prevent the Frostbelt from completely losing out. SMSAs in Texas, California, Florida, and Massachusetts dominate net job gain rankings.

Absolute Job Loss: The Bottom Ten.—A total of 86 SMSAs, or one-third, lost high-technology employment between 1972 and 1977. The median employment loss was 741 employees. The State of New York was the biggest loser, with the metros of New York and Syracuse posting a combined loss of 14,491 jobs. Two Sunbelt metros, Miami and Los Angeles, also suffered significant losses during the period. The group of losers is relatively homogeneous when contrasted to the winners in that they are predominantly older big-city industrial metropolises. In three cases, Miami, FL, Decatur, IL, and Parksburg, WV-OH, absolute losses in employment translated into large negative percent changes as well. Eighty percent of the largest high-technology losers can be loosely characterized as older Northeastern industrial cities. But the inclusion of Los Angeles and Miami metros in this group shows that adverse high-technology loss is also a phenomenon in mature Sunbelt big-city SMSAs. This is true despite big job gains in surrounding metro areas in both California and Florida.

Table C-5.—The Top Ten Gainers and Losers of High-Technology Jobs, Percent Employment Change, 1972-77

Winners	Percent change	Number of plants		Losers	Percent change	Number of plants	
		1972	1977			1972	1977
Lawton, OK	2,266.97	5	130	Columbia, MO	−82.48	161	28
St. Cloud, MN	1,265.66	85	1,173	Eau Claire, WI	−67.29	2,726	889
Boise, ID	729.31	73	607	Newport News, VA	−54.51	5,257	2,391
Santa Rosa, CA	360.58	834	3,842	Parkersburg, WV-OH	−51.11	7,168	5,564
Lakeland, FL	266.69	3,095	11,228	Decatur, IL	−455.85	6,827	5,090
Lubbock, TX	237.44	1,294	4,366	Bradenton, FL	−55.83	691	381
Topeka, KS	237.35	175	594	Clarksville, TN-KY	−41.09	141	83
Laredo, TX	220.84	36	117	Grand Forks, ND-MN	−40.80	62	37
Savannah, GA	204.78	2,783	8,482	Miami, FL	−40.38	16,306	9,723
McAllen Pharr-Edinburg, TX	181.54	110	311	Gadsden, AL	−39.87	1,225	78

SOURCE: Office of Technology Assessment.

Table C-6.—The Top Ten Net Employment Winners and Losers, 1972-77

Winners		Losers	
San Jose, CA	31,909	New York, NY	−8,975
Anaheim, CA	30,612	Philadelphia, PA	−8,586
Houston, TX	18,932	Cleveland, OH	−8,170
San Diego, CA	16,782	Miami, FL	−6,584
Boston, MA	15,173	Syracuse, NY	−5,521
Dallas, TX	12,067	Baltimore, MD	−4,245
Worcester, MA	9,893	Jersey City, NJ	−4,062
Oklahoma City, OK	8,363	Parkersburg, WV-OH	−3,664
Lakeland, FL	8,132	Los Angeles, CA	−3,220
Phoenix, AZ	7,976	Decatur, IL	−3,130
Median gain	248	Median loss	740

SOURCE: Office of Technology Assessment

Net Changes in High-Technology Plants

Net changes in high-technology plant location offer an approximate measure of the location of new high-technology growth. This group strongly resembles those places with the most significant net employment changes, though there are several anomalies. To begin, the median net change in plants across both gainers and losers was nine additions. Most metros gained plants—214 out of 264. Another 17 places experienced no plant change, while 33 others had net plant losses.

Absolute Plant Gain: The Top Ten.—Half of the top 10 plant gainers matched their prominence in job gain: Anaheim, San Jose, Dallas, Houston, and Boston. However, another five did not gain employment in proportion to new plants. Los Angeles, for instance, was the ninth largest job loser even though it was the second largest plant gainer. This suggests that Los Angeles is still hosting the growth of small, experimental or specialty high-technology plants while losing out in the competition to maintain larger scale, more standardized operations.

Three new entrants to the top 10 high-technology gainers are in this group: Detroit, Minneapolis-St. Paul, and Chicago. Two of the three are particularly surprising: Detroit and Chicago. In all three cases, it appears to be smaller plant growth that accounts for higher plant than job gains. Detroit's performance must be weighed against losses in the auto industry, which is not included in the high-technology set. Furthermore, our findings are limited to the mid-1970's period, prior to the worst reverses in the auto industry.

Absolute Plant Losers: The Bottom Ten.—The top net plant losers, with the exception of Port Arthur, TX, are predominantly Northeastern and Midwestern. As seen in table C-7, New York shows the biggest plant loss with three of the State's 10 metropolitan areas—New York, Albany-Schenectady, and Elmira—losing a net total of 175 plants. Among this group the magnitude of loss differs dramatically: New York metro lost 159 plants, almost 10 times as many as the next loser, Jersey City, NJ, with 17. Thus *within* regions and *across* States, trends may be of different orders of magnitude.

State and Regional Comparisons of Net Employment Change

Popular discussions of high-technology growth often treat certain States and regions as winners or losers, implying a high degree of homogeneity within them. Our

Table C-7.—The Top Ten Net Plant Winners and Losers, 1972-77

Winners		Losers	
Anaheim, CA	464	New York, NY	−159
Los Angeles, CA	367	Jersey City, NJ	−17
San Jose, CA	339	Elmira, NY	−9
Dallas, TX	276	Muncie, IN	−9
Chicago, IL	224	Albany-Schenectady, NY	−7
Houston, TX	204	Port Arthur, TX	−7
Boston, MA	191	East Lansing, MI	−7
Minneapolis, MN	158	Wilmington, DE	−6
San Francisco, CA	151	Johnstown, PA	−5
Detroit, MI	145	Kokomo, IN	−5
Median gain	9		

SOURCE: Office of Technology Assessment

data indicate that this generalization is not warranted, particularly on a State-by-State level. A number of supposedly high-technology States, such as Texas, California, and Massachusetts, show extraordinary internal variation in plant and job change across metropolitan areas. Table C-8 ranks States on the basis of proportions of SMSAs experiencing positive high-technology job growth. In California, for instance, five of its 17 SMSAs posted job losses in high-technology sectors between 1972 and 1977. Similarly, in Massachusetts, two of its five SMSAs were high-technology losers.

A brief glance at the regional distribution of high-technology metro employment loss underscores the distinct variability of high-technology employment change described above. However, by imposing regional groupings there is a modest support for generalizations about broad interregional divergence as seen in table C-8. Using a loose regional breakdown which puts Texas in the South and the Plains States in the Midwest, the four regions stack up as expected, with the largest number of metro net employment losers concentrated in the Northeast, followed by the Midwest. Contrary to the literature on regional antagonism, however, the West rather than the South had the fewest number of metropolitan losers, though the difference is small. If we were to classify Texas in the West rather than the South, the difference would be considerably greater. Given these findings, perhaps the war between the States breaks down on an East-West rather than a North-South axis.

Table C-8.—Regional Comparison of Metro Area Net Employment Change

	Number of metropolitan areas	Employment loss	Plant loss
West:			
Arizona	2	0	0
Colorado	5	0	0
Hawaii	1	0	0
Idaho	1	0	0
Nebraska	1	0	0
Nevada	2	0	0
South Dakota	1	0	0
Utah	2	0	0
Alaska	1	1	0
California	17	5	0
Montana	2	1	0
New Mexico	1	1	0
Oregon	3	1	0
Washington	5	2	0
North Dakota	0	0	0
Wyoming	0	0	0
West total	44	11	0
Percent metros that lost employment =0.25			
South:			
Mississippi	3	0	0
Oklahoma	4	0	0
Alabama	8	2	0
Florida	16	5	1
Georgia	6	3	1
Kentucky	3	2	1
Louisiana	7	2	0
North Carolina	7	2	0
South Carolina	3	1	0
Tennessee	5	3	0
Texas	25	3	3
Virginia	6	2	1
West Virginia	4	1	0
Arkansas	3	0	0
South total	97	26	7
Percent metros that lost employment = 0.26			
Midwest:			
Illinois	9	3	2
Indiana	12	7	4
Iowa	7	1	0
Kansas	3	0	2
Michigan	12	4	2
Minnesota	6	1	0
Missouri	4	2	1
Ohio	14	6	2
Wisconsin	8	4	1
Midwest total	75	28	13
Percent metros that lost employment = 0.37			
Northeast:			
Connecticut	4	1	0
Delaware	1	0	1
Maine	2	1	0
Maryland	2	1	0
Massachusetts	5	2	1
New Hampshire	1	0	0
New Jersey	8	5	2
New York	10	6	4
Pennsylvania	12	7	3
Rhode Island	1	0	0
Vermont	0	0	0
Northeast total	46	23	11
Percent metros that lost employment = 0.48			

SOURCE: Office of Technology Assessment.

Why High-Technology Industries Are Where They Are

A third major question is, what explains the existing array of high-technology economic activity and what forces are redistributing it across the country? We have demonstrated that there is indeed great diversity in high-technology job and plant patterns and that dramatic shifts in location have occurred in the 5-year period studied. Explaining these distributions and changes in them was the final task of our project.

The literature on high-technology industries suggests that a set of locational characteristics are most apt to attract high-technology activity. Some of these factors are common to all manufacturing; others are assumed to be unique to this group of industries. In constructing a model of high technology attractiveness and job/plant shifts, we included five sets of variables intended to represent the major forces hypothesized in the literature.

First, we modeled in three features of labor supply: wage rates, unionization rates, and area unemployment rates. We expected to find the first two negatively correlated with high-technology job and plant shifts and the latter positively correlated, on the supposition that high wages, labor militance, and tight labor markets all discourage high-technology job growth.

Second, we modeled in a set of three business climate features: presence of specialized business services, presence of first-rate research facilities and talent, and incidence of defense spending. We expected that high levels of business services, research talent, and defense spending would all be positively related to net high-technology job and plant gains as well as to high levels of high-technology dominance in regional economies.

Third, we added a set of basic infrastructure features: transportation networks, both air and highway, and utility rates. We expected to find that access to superior freeway and airport facilities would positively contribute to high-technology job and plant shifts, while relatively high utility rates would discourage them.

Fourth, we modeled in a set of amenities features which are widely believed to be particularly attractive to a high-technology labor force, particularly the professional/technical personnel and entrepreneurs. These included availability of a superior cultural environment, reasonable housing prices, a relatively unpolluted atmosphere, a mild climate, good schools for children and post-secondary educational options. In each case, we expected high-technology plant and job growth to be related to a positive ranking.

Finally, we included a set of socioeconomic variables which we suspected might be related to high-technology growth and enclaves based on case study work in California. These included the percent of minority workers in the population, to which we expected high-technology performance to be negatively related, and the proportion of relatively conservative voters in the population, which we expected to be positively related. A list of the precise formulation of each of these variables, and their data source, appears at the end of this appendix.

In order to capture high-technology spatial patterns, which is what we wished to analyze with these metropolitan features, we formulated three different endogenous, or dependent, variables. First, we constructed a ratio of high-technology dependency (discussed in the previous section) which captured the degree to which individual SMSAs were highly or not at all dependent on high-technology industries for their vitality. Second, we constructed an employment change variable by simply subtracting the total employment for each SMSA for 1972 from that for 1977. Because we had a large number of cases, especially at the disaggregated industry-by-industry level, of no high-technology employment in the initial period, we decided not to employ percent changes as a method of measuring job shifts. (We considered throwing out all such cases, but this would bias our sample; however, a preliminary run to compare the results indicated that we would not significantly increase the degree of explanation by using percentage changes.)

Third, we constructed a similar variable for analyzing plant shifts. Because in these latter two cases we would be regressing absolute job and plant shifts on a number of relative (e.g., per-capita defense spending) measures, we corrected for the influence of sheer size of SMSA by adding in on the right-hand side, as an explanatory variable, total size of the labor force. This variable would pick up the effects of differential size—i.e., it would account for the fact that a large SMSA like San Jose could be expected to post more absolute job growth than a small one like Grand Forks, ND.

Methodology

Although we had a number of general hypotheses guiding the regression analysis, given the large number of presumed explanatory variables, we chose to use a stepwise regression procedure, rather than specifying a complete model before hand. Stepwise regression allows the researcher to explore the relationship between the independent and the dependent variables. In the context of this project we used a forward stepwise inclusion procedure supported by the SPSS statistical package for the Social Sciences. Using this procedure, the computer selected variables in descending order based on preexisting statistical criteria which we specified. The order of inclusion using this procedure is determined by the respective contribution of each variable to explained variance. In other words, the variable that explains the greatest amount of variance unexplained by the variables already in the equation enters the equation at each step.

Three parameters were set to guide the inclusion of independent variables in our regressions (N size, F statistics, and T tolerance). N size refers to the number of variables to be included in the equation. We specified that any or all of the 19 variables could enter the equation as long as they met the remaining criteria.

The second parameter, F, relates the F ratio computed in a test for significance of a regression coefficient. In stepwise regression, at each step of the analysis, F ratios are computed for variables not yet in the equation. This parameter was set to the default as prespecified by the statistical program.

The third parameter, T, refers to user-specified tolerance. The tolerance of an independent variable being considered for inclusion is the proportion of the variance of that variable not explained by the independent variables already in the equation. This parameter was set to allow all variables into the equation in which the proportion of variance not explained by other independent variables exceeded 0.1 percent. In this analysis, we chose to apply rather liberal statistical criteria in order to ensure that the maximum number of variables would be included in the individual industry and aggregate regression results.

Explaining the Geography of Aggregate High-Technology Industries

In order to test for association between aggregate high-technology activity and the characteristics of metropolitan areas described above, we ran three regressions. First, we looked for relationships between metro features and the 1977 high-technology ratio. The results from this regression tell us something about what features high-technology-dependent metros display. Second, we looked at net employment change over the period 1972-77. This regression tells us which features of metro areas are most strongly associated with positive and negative job shifts. Third, we regressed net plant change over the same period on the same set of variables, to find out the direction and strength of relationships dominating plant shifts.

Factors Associated With High-Technology Dependence

Only five metro features were found to be significantly associated with high-technology jobs as a proportion of area labor force. Together they explained only 18 percent of the variation across the 218 metros for which we had data for all 19 independent variables. The single strongest factor was defense spending, which displayed the expected positive correlation with heavy high-technology dependence. It accounted for one-third of the explained variation. Percent Hispanic was the second most important factor; high-technology dependence was negatively related to the presence of this group in metro areas. Percent black was similarly negatively correlated with high-technology dependence, which also confirmed our hypothesis. Both these findings suggest that heavy reliance on high-technology is not associated spatially with minority populations. This finding is interesting in light of the fact that minority composition was not significant in either the aggregate or individual cases of change in high-technology plants and jobs.

The final two factors which were significant in explaining high-technology dependence were industrial utility rates and unemployment. In each case, the variable explained less than 2 percent of the total variation. However, both had signs opposite of what might be expected. Strong high-technology dependence was positively related to high utility rates and low unemployment rates. We think that in the case of this particular dependent variable, that high-technology activity may be creating jobs, therefore lowering unemployment, rather than industries migrating to areas with surplus labor.

Explaining the Geography of High-Technology Job Shifts

Our results for the regression in which employment change over the period 1972-77 was regressed on the set of independent variables were somewhat better than for high-technology dependence in 1977. Overall, we were able to explain 29 percent of the variation across 218 metro areas. Nine, or exactly half, of our variables contributed to this explanation, although sometimes the direction of the relationship was unexpected.

Housing prices, freeway density, and per-capita defense spending together accounted for half of the explained variation. Defense spending was positively related to job shifts, as expected. However, the other two variables showed the opposite of the predicted signs. Housing prices were positively associated with high-technology job shifts, rejecting the hypothesis that high housing prices drove high-technology jobs away from certain areas in the period studied. This finding might change if we used a different year to compute housing price, although we would have to assume that the *relative* differentials in housing price across metros changed in order to make this exercise meaningful. More likely, high-technology job growth places upward pressures on housing prices, reversing the causal relationship implied in the model. The negative relationship found between freeway density and high-technology job growth may simply be the result of a misspecification problem, on which we speculate in the final section.

Six other factors each contributed less than 3 percent apiece to explaining total variation. Several of these—unionization rates, percent black, educational options, and 1977 labor force—all had the expected signs. High-technology job shifts were negatively related to high levels of unionization and to large proportions of blacks, and positively related to metro educational options and the size of the 1977 labor force. The relatively low degree of explanation added by this last variable suggests that a great deal of high-technology job growth is not happening proportionately to size of place. Some degree of multicollinearity reduced the significance of the estimates for the minority and educational options variables when the full set of independent variables were included in the regression.

Two additional variables, the arts index and the pollution index, both contributed to explaining high-technology job shifts, but both had unexpected signs. High-technology job growth was negatively associated with a high rating on the arts index, suggesting that the supermetros which have the greatest cultural advantages are not attracting net job growth in high-technology industries. A high pollution rating was positively correlated with high-technology job growth, suggesting that poor industrial air quality is not a significant deterrent to new high-technology job growth in the aggregate. This may be because many high-technology industries are "light" in nature and do not add much to environmental degradation.

Explaining the Geography of Aggregate Plant Shifts

The regression relating net change in high-technology plants to the features of metro areas yielded much better results. Almost 68 percent of total variation was explained by nine of the place characteristics. Six of these were the same ones which turned up in the job change regression, with the same signs in every case. However, their order of importance was quite different.

Size of the labor force in 1977 explained fully 26 percent of all net plant change. This simply means that absolute net gains in plants were greatest in places where the labor force was largest. This was to be expected, since it was our way of dealing with the impossibility of using percentage changes in plants as the dependent variable. The second most important factor was presence of Fortune 500 headquarters, which explained an additional 24 percent of the variation, but in the opposite direction than that expected. Metropolitan areas which were large net plant gainers are those which lack corporate headquarters, while those metropolitan areas which do host them have lost out in high-technology plant shifts. This suggests that the bulk of high-technology manufacturing plants are not linked spatially to corporate headquarters functions. While this would not be surprising for manufacturing in general, it is somewhat contrary to popular impressions of the location of innovative sectors. Of course, as we shall see below, this variable does indeed exert a strong attractive force on a minority of sectors taken individually.

The rest of the variables which were significant in this regression all contributed only modest amounts to explaining total variation—in every case, less than 3 percent. The arts index was again negative, house prices positive, and freeway density negative—all opposite to the model's presuppositions, just as was true in the job change regression. Defense spending, percent black, and unionization rates were all significant and showed the expected sign. Educational spending made its first showing in this regression, but it had an unexpected negative sign. High-technology plants are not as a whole moving toward places with relatively high per-capita school spending.

Summarizing the Aggregate Findings

Overall, only two variables are consistently significantly related to different measures of high-technology locational patterns. Per-capita defense spending and percent black population contribute to explaining high-technology dependence as well as changes in jobs and plants over time. In each case the characteristic yielded the expected sign. Comparing job and plant shifts alone, labor force (which was not included in the high-technology dependence equation) and unionization rates were also significant and in the expected direction. Three unexpected influences—housing prices positively, freeway density and arts index negatively—also turned up as significant for explaining both plant and job shifts. Pollution and educational options helped to explain job shifts but not plant shifts, while Fortune 500 headquarters and educational spending per capita were significant for plant but not job change.

However, the most important fact to underscore in summarizing these results is that overall they are not very impressive. Discounting the labor force variable, which is really an attempt to convert absolute to relative changes, in none of these cases did the total degree of variation explained by significant variables exceed 37 percent (see above). While this is on average quite good for cross-sectional analysis, we were unable to explain the remaining variation in high-technology spatial patterns. While our measures of the features of places may be imperfect, due to data limitations, the relatively poor results must be taken seriously because the phenomenon we are trying to explain—high-technology spatial activity—is captured with extraordinary richness of detail on both an industry and a place basis in our analysis. We believe that these results offer strong support for our view that individual high-technology industries are highly heterogeneous and display quite disparate spatial tendencies which can only be understood by analyzing disaggregated sectors.

Furthermore, great caution should be used in referring to those characteristics which did turn out to be significant as "determinants" of high-technology location. While per-capita defense spending did turn out to be positive, significant, and present in all three regressions, it is important to remember that it accounts for only 6, 4, and 2 percent of total variation respectively. The coefficients on unionization rates are similarly significant and negative, but contribute less than 2 percent in each case. Other than labor force, Fortune 500 headquarters is the only variable which explains more than 10 percent of total variation and it appears only in the plant shift results. Since it is unexpectedly negative, it tells us much less than we would like. Knowing that corporate headquarters are more apt to be negatively rather than positively associated with net plant change does not give us a great deal of insight into why high-technology plants locate where they do.

Explaining the Locational Tendencies of Individual High-Technology Sectors

The results of the four-digit industry regressions show a great deal of variation—both across industries and across dependent variables. Using net employment change as the dependent variable, only 29 of the 100 industries had explained variation greater than 20 percent. Of these, labor force accounted for more than 10 percent of the explained variation in 12 of the 29. Since our results for net plant change were better than the rather poor results using employment change, we focus in the following discussion on the former. It portrays the model in the best possible light.

Contrary to our original expectation, moving to a more disaggregated sectoral level did not produce universally better results with our independent variables. While regressions were computed for all 100 industries using plant change as the dependent variable, 39 industries had less than 20 percent explained variation and are consequently not reported here. On the whole, the remaining industry regressions were less informative than expected; in all but four cases less than 51 percent of the variation was explained. These four exceptions were General Industrial Machinery, 3569 (R^2 .7721), Instruments 3823 (R^2 .719), Electronic Components, N.e.c. 3679 (R^2 .700),* and Industrial Chemicals 2899 (R^2 .532). In all but Industrial Chemicals, 2899, labor force explained more than 50 percent of the variation.

Among these four industries all were consistent across significant independent variables. In the cases where labor force was highly significant, arts were negatively correlated. In three of the four industries, Fortune 500 headquarters was also negatively correlated, suggesting that net plant change was away from large metro areas. House spending was significant and positive in three of the four industries. A third variable, major university, was also unexpectedly negative—providing yet more reinforcement for the negative major metro association with these industries. In two of the four industries, both climate and percent black were significant and in the expected direction. On the whole, this group of four industries showed surprising similarity in factors associated with spatial location.

A second group of industries with between 40 and 50 percent explained variation lacked the degree of consistency found in the previous group. In three-quarters of these 14 industries, more than half of the explained variation was accounted for by labor force. In the four industries where labor force accounted for less than 25 percent of the explained variation, the direction of the variable loadings were consistent across three of the four. Fortune 500 headquarters were strongly negative in all four industries.** In three of the four industries, 3841, 3675, and 2851, airport access was significant but in the wrong direction in two of three cases. The same sign reversal was found in the pollution variable: one industry, Paints and Varnishes 2851, had the expected sign, but Electrical Capacitors showed a negative relationship. In two of the four cases, Surgical and Medical Instruments 3841 and Electronic Capacitors 3675, industrial utility rates were negatively associated with plant difference.

The lack of explained industry variation was disappointing and suggests that high-technology industries individually may be responsive to locational factors different from those commonly assumed. The lack of explanation led us to carefully examine those industries popularly thought of as "high-tech" to see if the attributes most commonly assumed to be associated with high-technology industry growth held for at least this set. By "popular" we mean industries which have a shared set of characteristics: high employment growth rates in the current period; high proportions of professional and technical personnel in the labor force; and large R&D expenditures as a proportion of industry sales. Seven industries were chosen to report on here—Computers 3573, Semiconductors 3674, Biological Products 3831, Telecommunications Equipment 3661, Missiles 3761, Aircraft Engines 3724, and Engineering Instruments 3811.

On the whole, the results for these high-technology industries were less illuminating than expected. In only one industry, Computers, was more than 40 percent of the variation explained. In this industry, 23 percent of the explained variation is accounted for by labor force. In four of the seven industries, labor force was strongly positive and significant; in the remaining three, labor force was negatively related. This negative relationship may in part be explained by the relatively dispersed nature of these industries as seen in the entropy index. In this case, smaller as well as big metros have earned large net plants additions.

Somewhat unexpectedly, more than five of the seven "popular" high-technology industries appear repelled by metropolitan forces. That is, these industries were not attracted to places that had positive ratings on the Fortune 500, Arts, and Labor Force variables. As with the aggregate industry regression, four of the seven industries were negatively related to Fortune 500 headquarters. Only Missiles had a positive and significant relationship to this variable. A third variable accounting for significant variation within industries was defense spending. Two of the three industries had the expected sign: Telecommunications and Computers, with explained variation of 10 and 2 percent respectively. Missiles showed defense to be negatively related to plant change. This negative relationship can be explained in part by suggesting that missile employment, which declined overall during the period (−65 percent), has diminished precisely in those areas where defense spending remains high.

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*"N.e.c." is an abbreviation for "not elsewhere classified."

**As suggested in the discussion of the aggregate industry regressions, this implied that these four industries are not associated with super metropolitan areas. This supposition is reinforced by the negative relationship between the arts index in two of the four industries.

While both the business press and selected State policy analysis suggest that high-technology industrial location is motivated by low housing prices, in general this was not borne out in this analysis. In three of the seven industries, house spending was positive and strongly significant. House spending was the single most important variable in explaining Engineering Instruments, accounting for 16 percent of the explained variation.

Another popular notion—that there is a positive relationship between high-technology industry location and education opportunity—was not found to be consistently significant across the industries examined. As originally hypothesized, educational options were positively associated with only three of the seven industries. And whereas we expected that industries such as Semiconductors and Computers would be particularly sensitive to the availability of educational resources, the individual industry results imply that, relative to other variables, educational options were not significant. They were significant and positive, however, in explaining Biological Products, accounting for 16 percent of the variation.

These results suggest that popular notions of what influences high-technology location are not universally borne out by individual industry regressions. Perhaps in the case of house spending and educational options, high-technology plant changes are independent of these influences because individual mobility compensates for them.

At the outset we expected that detailed four-digit industry regressions would be particularly amenable to explanation using the place-based variables included here. To our surprise the results, despite the detailed nature of the data base, were not conclusive, and in a number of cases the explained variation was in the opposite direction to that hypothesized. These results suggest that to understand the location of this very heterogeneous group of industries, disaggregated industry and place-based analysis is the more appropriate means.

For example, the model used here clearly ignores characteristics associated with places such as geographically concentrated entrepreneurship, which we know from other evidence to explain the location of high-technology industry in a number of popular high-technology centers such as Phoenix, AZ, and San Jose, CA. Despite the lack of explanation found in the industry regressions, the lack of significance associated with variables such as unionism and wage rates confirms our expectation that all industries face these factors and that it is only the marginal case which uses such individual variables to make the location decision.

A Review of the Performance of the Explanatory Variables

The results of the individual four-digit industry regressions offer us a chance to remark on the incidence and direction of influence of our independent variables. Overall, we can throw out approximately half of our variables as almost universally lacking in significance. Among the rest, rankings can be constructed on the frequency and consistency of their influence on individual high-technology industry shifts.

Insignificant Factors

First of all, we can eliminate 10 of our 19 independent variables from consideration at the disaggregated level. In the 61 industries where we could explain more than 20 percent of total variation, these 10 variables were significant—but in only 5 percent or fewer cases did they contribute more than 2 percent to the explanation. This was true for both job and plant regressions. These variables are listed in table C-9.

Among these, several exhibited the expected sign quite consistently in those few cases where they did show up. Unionization was generally negatively related, while climate, percent Republican, and educational options were almost universally positive when present.

The extremely poor showing in individual industry cases of variables such as unionization rates, educational options, educational spending, and percent black underscores the fact that the sum is often more than, or different from, its parts. Each of these appeared at least once as significant in the regressions on aggregate job and plant shifts. Educational options might be explained by its relatively high rate of correlation with two other variables—airports and arts—both of which showed up frequently

Table C-9.—Variables Insignificant in Explaining High-Technology Industry Locations

Educational spending	Unemployment rate
Industrial utility rates	Percent Republican
Manufacturing wage	Percent Hispanic
Unionization rate	Educational options
Climate index	Percent black

SOURCE: Office of Technology Assessement.

in the case of individual industries. However, in the cases of the other three, we must assume that they often act as relatively minor influences critical for only a very few industries.

The composition of this set of 10 poor performers suggests some tentative speculations about the relative importance of our original groups of characteristics. The labor force variables (wage rates, unionization rates, and percent unemployed) have all been eliminated. The socioeconomic variables (percent black, percent Hispanic, and percent Republican) have also been eliminated. Half of the "amenities" variables also disappear. Overall, this suggests that labor-associated features are not important determinants of high-technology locational change, at least not for explaining change in the period studied. Perhaps they might be more important since 1977, but we will have to await publication of the 1982 Census of Manufactures for confirmation. A possible interpretation of this finding is that in this era of high labor mobility, employers find it relatively easy to create a labor force in locations to which they are drawn for other reasons. People, in other words, readily follow jobs in high-technology sectors rather than vice versa.

On the other hand, several of these variables may be better discriminators of high-technology changes *within* metro areas and between metro and nonmetro sites. We anticipate, for instance, that educational spending, unionization rates, percent Republican and percent minority are more important in explaining whether high-technology industries locate in inner cities versus suburban or exurban areas than they are across metros. In other words, they may determine intrametropolitan, rather than intermetropolitan, shifts. Similarly, we believe that educational options, wage rates, and industrial utility rates may explain more of the variation across metropolitan, small town, and rural locations than they do among metros. Confirming these hypotheses lay beyond our current resources and, in the latter case, available data.

The Most Common Factors Associated With Metropolitan High-Technology Shifts

Nine of our independent variables turned up frequently and contributed more than 2 percent to total explanation in the 61 plant shift regressions. These variables, listed in descending order of frequency, are listed in table C-10. This table also ranks the same variables in descending order on their support for the hypothesized sign of the modeled relationship. Those at the top of this list consistently confirmed the expected relationship, while those at the bottom consistently reversed the expected direction of association. Those in the middle are variables which, while often strong determinants, had contradictory effects on different industries.

Labor force, as expected, was the most commonly confirmed associate of absolute plant gain. Thus, in large metropolitan economies plant gains were generally proportionately large, all else being equal. However, in a minority of cases (21 percent), the opposite was true; in these sectors, metros with large labor forces experienced relatively smaller gains or negative plant shifts compared to smaller economies. For the most part, these exceptions occurred in heavy industries such as paints, carbon black, ammunitions, motors, industrial patterns, and electrical industry apparatus. However, several relatively new and fast-growing sectors also fell into this group: Space Vehicle Parts 3769, Engineering 3811, Laboratory and Scientific Instruments, and Measuring Instruments 3823. Further qualitative research might be done to explain why these sectors are attracted to metros with smaller labor forces.

Fortune 500 was another frequent contributor to individual industry locational explanation. But as in the aggregate case, the relationship was negative in the majority of cases (72 percent). It was the exceptional high-technology industry that was attracted or maintained by Fortune 500 headquarters metros. Several of these are clearly business service-related—e.g., Photographic Equip-

Table C-10.—Most Commonly Occurring and Consistency Ranking of Variables Explaining Net Plant Change

Most common rank[a]	Frequency (number of cases)	Consistency ranking[b]	Percent cases sign expected
Labor force 1977	48	Airports (+)	90%
Fortune 500	36	Defense spending (+)	88
Arts index	22	Labor force (+)	79
Major universities	14	Major universities (+)	57
Pollution index	13	Pollution (−)	38
Housing prices	13	Fortune 500 (+)	28
Freeway density	11	Arts (+)	27
Airports ranked	10	Freeway density (+)	0
Defense spending	8	House prices (−)	0

[a] The frequency rating shows the number of successful individual industry regressions (N=61) in which this variable was a significant contributor to total explanation. Variables which were significant at the 0.10 level.

[b] Percentages here show the percentages of cases in which the variable displayed the expected sign in the regression.

SOURCE: Office of Technology Assessment.

ment 3861, and Office Machines 3579. But machining sectors, such as Industrial Patterns 3565 and Metalworking Machinery 3549, were also strongly oriented toward Fortune 500 cities, perhaps because both produce relatively custom-made items that are often designed in corporate headquarters. Harder to explain are the orientations of the heavier industries of Petroleum Refining 2911, Cyclic Crudes 3865 and Ammunition 3483 to Fortune 500 metros. Perhaps a few places like Houston, San Francisco, and Los Angeles explain the oil-related cases. But more importantly, the rest of our high-technology sectors seem to be repelled by Fortune 500 headquarters cities.

The third most frequently appearing factor was the arts index. It was quite similar to the Fortune 500 variable in having an unexpected negative loading in 73 percent of the cases. Since the arts index is also an expression of supermetro status—indeed, its correlation with Fortune 500 is the highest in the set—we speculate that it is picking up the same spatial tendency. That is, a rich cultural environment is not a significant pull factor for high-technology plants and is more apt to be associated with other features repelling (or inviting shutdowns of) high-technology plants.

Two additional factors—major university and pollution index—were frequent contributors to explanation but with contradictory effects on different sectors. Major universities had the expected positive effect on net plant change in only 57 percent of significant regressions. These were a heterogeneous group of industries which might be associated in some way with university research labs. They included synthetic fibers, industrial patterns, and measuring and control devices, which might be spawned by or drawn to the research labs of chemists, engineers, and medical schools respectively. The sectors which were repelled by university atmospheres include special cleaning substances, explosives, miscellaneous machine tools, and driving gears. The interpretation here might be that these sectors require few innovations and no other characteristics associated with major universities.

Pollution is the other variable with strong dualistic patterns. It is a significant discourager of net plant change in only 38 percent of the cases. These included what appear to be particularly obnoxious conversion processes such as oil refining, ordnance production, special cleaning substances, and the production of industrial trucks and tractors. On the other hand, high levels of industrial pollution were not a deterrent to—in fact were positively associated with—net plant additions in calculators, semiconductors, engineering lab instruments, fluid meters, and other measuring devices. These are all relatively light manufacturing processes and thus would not be discouraged from locating in relatively poor industrial air-quality areas. However, missiles and machine tools also fall into this category. It may be the case that other factors associated with environmentally taxed industrial metros are so critical to these industries that they will locate there despite the potential increase in degradation and despite high environmental cleanup compliance costs.

Four other variables are relatively common contributors to explaining sector change, although they occur in fewer cases than those described so far. Every one of them, however, has a purer record for consistent sign than do those occurring more frequently. Two, airport access and defense spending, have a very consistent incidence of positive association with high-technology plant growth—90 and 88 percent respectively. On the other end of the spectrum, freeway density and housing prices both had a universally perverse sign. Freeway density, which was expected to be positively correlated with high-technology growth, was negative in every case where it was a substantial contributor to an industry's explained plant shift. As noted above, this may be a problem with the variable's construction. Housing prices were universally positively associated with high-technology plant additions, a fact we have already attributed to a reversal in the causal relationship.

In sum, the set of independent variables performed quite disparately in the individual industry regressions. Only three (airports, defense spending, and labor force) were both frequent significant contributors and consistent in supporting the model's original suppositions. Two others, freeway density and housing prices, were frequent contributors, but consistently contradicted the model's hypothesized direction of impact. Four others—major university, pollution, Fortune 500, and the arts index—were often significant but operated quite variably in both repelling and attracting high-technology plant shifts. The performance of each in explaining job, rather than plant, shifts was relatively similar although much smaller in magnitude.

These more powerful factors in explaining high-technology locational change fall much more frequently into the broad categories of conditions of doing business (Fortune 500, major university, and defense spending) and transportation and communications (freeway density, airports ranked) than do those associated with the labor force. The amenities variables that mattered (arts, housing price, and pollution) were among the most highly contradictory or consistently unexpected in sign; another fact that reinforces the speculation that it is not employee-related features that draw high-technology industry but other factors that influence profitability, on both the supply and demand side.

Although some high-technology industries are increasingly having a hard time surviving in places where housing prices are relatively high and transportation is congested, as is the case in Silicon Valley, this may be a relatively freak or precocious case. Or, the agglomerative needs of a new, highly innovative industry may keep it in a supermetro even though some of its costs, direct or indirect, are beginning to rise.

Conclusions

Our conclusions can be set out succinctly:

1. **Homogeneity.** High-technology industries are not a homogeneous group; they are highly diverse in their rates of growth (or decline), their potential for plant or job growth, and their patterns of location.

2. **Growth.** While some high-technology industries (Computers, Petroleum Refining) added large numbers of jobs between 1972 and 1977 and others (Scientific Instruments, Measuring and Controlling Instruments) achieved very high percentage growth, over one-third of these industries lost jobs and more than two-fifths grew at less than the manufacturing average.

3. **Geographical concentration.** While some high-technology industries (Miscellaneous Missile and Space Vehicle Parts; Guided Missiles and Space Vehicles; Tanks and Tank Components) were highly geographically concentrated on one or another of the measures used, others (Fertilizers; Dies and Industrial Molds; Miscellaneous Electronic Components) were highly dispersed. The main explanation seems to be type of product, character of major consumer, and dependency on natural resources. Thus, defense and space-oriented manufactures were highly concentrated, presumably because of spending and procurement policies; resource-based industries (Carbon Products; Alkalies and Chlorine; Synthetic Rubber; Manmade Fibers) were also concentrated; but industries producing heavy or bulky inputs for dispersed customers (Fertilizers, Paints, Chemicals) were highly dispersed. Many fast-growing high-technology industries—Computers, Semiconductors, Biological Products, Measuring Devices, Industrial Controls, Optical Instruments, Machine Tools—were moderately dispersed. Constituent parts of major industrial groups tended to have different degrees of concentration-dispersion than the groups themselves. Between 1972-77, the great majority of industries tended to disperse; the sole exceptions seemed to be military-related sectors and bulk materials processing. Though most innovative, fast-growing high-technology industries followed the general dispersion trend, a few—Semiconductors, Resistors, Telephone Equipment—further concentrated.

4. **High-technology-dependent SMSAs.** These are a diverse group, some not well-known (Melbourne-Titusville around Cape Canaveral in Florida; Wichita, KS, an important base for aircraft maintenance and production). SMSAs with the lowest high-technology base are all—contrary to myth—in the Sunbelt; Texas has three.

5. **Growth and change, 1972-77.** This is very difficult to generalize because the patterns are different—for absolute and for percentage growth, for plants and for employment. Absolute plant growth was predictably greatest in some bigger SMSAs, four of which—Detroit, Minneapolis-St. Paul, Chicago, Boston—were in the older industrial belt. But percentage plant growth and percentage employment growth were fastest in medium-sized, free-standing SMSAs outside the Northeast. Biggest absolute employment gains were recorded in SMSAs with a high-technology reputation, led by San Jose (Silicon Valley), Anaheim, CA, Houston, San Diego, and Boston—plus two surprises, Lakeland, FL, and Oklahoma City. Within supposedly high-technology States, there is surprising variation: thus 5 out of 17 California SMSAs posted high-technology job losses.

6. **Explaining the aggregate patterns.** A basic hypothesis underlying this study—that the distribution and growth of high-technology industry could be statistically explained in terms of a number of key locational factors—has been resoundingly disproved. Out of 19 factors used for the analysis, only five (defense spending, percent Hispanic, percent black, industrial utility rates, and unemployment) were significantly associated with high-technology concentration of employment—and even they explained only 18 percent of the pattern. For employment change, the result was little better: nine variables explained 29 percent of the pattern. Plant changes provided the best level of statistical explanation, with almost 68 percent of aggregate variation explained by nine of the variables. But of this, size of labor force explained 26 percent—and this could be somewhat discounted since it must be related to absolute change.

7. **Explaining the patterns: individual industries.** Repeating the analysis for individual industries produced no better result. Indeed it appeared to dispel certain popular myths about high-technology industries: they do *not* appear attracted to areas with lower housing prices or areas with good educational options, or to be sensitive to trade union organization or wage rate differences. Nine of the factors—educational spending, industrial utility rates, manufacturing wage, unionization rate, climate, unemployment rate, percent voting Republican, percent Hispanic, and educational options—appear to have little or no relationship to growth of plants in individual high-technology industries. Only four—labor force, airports, defense spending and, less strongly, major universities—were significant contributors and also consistent in supporting the hypothesized relationships. Others—presence of major corporate headquarters, pollution, good arts availability, a well-developed freeway network, and low house prices—were significant, but the relationship was the reverse of that postulated. Overall, the most powerful factors seem to be business-related (lack, not

presence, of major industrial headquarters; presence of major university; high defense spending) or transportation and communication-related (presence of major airport; lack, not presence, of highly developed freeway net) rather than amenity-related (arts provision, housing costs, pollution), which seem to be either contradictory or perverse in their relationship to high-technology plant growth: the general tendency is for high-technology plant growth to be related to lack, not presence, of arts provision; high, not low, housing costs; presence, not absence, of pollution. This reinforces a speculation: that high-technology industry is not drawn—as often supposed—to locations attractive to employees, but rather is influenced by other factors that affect profitability. But this is somewhat speculative.

8. **Overall conclusion and policy implication.** The research has thus been rather less useful for what it has proved, than for what it has evidently failed to prove. Certainly, a whole host of factors—generally thought to be important and even critical in attracting high-technology industry—do not appear from this analysis to have much, or indeed any, significance. This may be surprising and even disappointing, but is clearly important in its negative way for policy formulation. Our most important conclusion is that the location and growth of high-technology industry is a very varied and disparate process which will require highly disaggregated industry-by-industry analysis.

Independent Variable Description

Air Pollution Index. This index consists of a ranking of metropolitan areas on the basis of measurable particulate pollution. Areas received a rating from 1 to 6 indicating insignificant to extreme levels of pollution. The variable was rescaled by reducing the increasing increments from 100, 200, etc., to 1, 2, 3, etc. The data was taken from the Environmental Protection Agency, "Air Quality Data: 1976 Annual Statistics."

Airport Access. This index of accessibility allocates a rating from 0 to 4 to areas with airports having the following designation: no airport, nonhub, small hub, medium hub and large hub. The numerical values assigned to the index are based on the percentage of U.S. passenger traffic handled. The values for the scaled increments are as follows: nonairport = 0; 1 = < 0.05 percent of total U.S. passengers served; 2 = 0.05 to 0.24 percent of total U.S. passengers served; 3 = 0.25 percent to 0.99 percent passengers served; 4 = 1 percent or more carried from the airport in 1978-79.

It is important to note that some areas, adjacent to large metros such as New York, do not have their own airport facilities but rather rely on the adjacent international airport services available. We considered assigning the same designation to these places without airport service as their adjacent metros. Areas which were less than 26 miles from the major airport were considered for inclusion, but upon closer examination we chose to list them as having no airport. A more complicated measure of transportation access based on a gravity model could have resulted in better, or at least different, results.

Arts Index. This index ranks places on the basis of available arts and cultural resources. Areas are ranked on the following characteristics: major university enrollment, symphony orchestras, opera companies, dance companies, theatres, public television stations, fine arts radio stations, museums, and public libraries. The index is additive, and was drawn from Rand McNally's "Places Rated" Almanac. The data comprising the index were collected for the 1977-78 period.

Black population 1970. The 1970 black population raw count was divided by the total population. The data were taken from the U.S. Bureau of Census, "State and Metropolitan Area Data Book, 1977."

Climate Index. Areas were rated on the following climatological characteristics: the number of very hot and very cold months; seasonal temperature variation; the number of heating and cooling degree days; the number of freezing days; the number of zero degree days; the number of 90 degree days. The index was constructed by initially assigning places 1,000 points and then deducting points for negative attributes. The data were published in "Places Rated" Almanac and were collected for the year 1978.

Defense Spending Per Capita. Metropolitan defense spending over $10,000 in contract value was divided by the population. Data source was the State and Metropolitan Area Data Book and was for 1977.

Educational Options Index. Metropolitan areas were rated on the basis of available educational options. This index includes information on the following items: the number of 4- and 2-year public and private colleges and universities, the availability of evening classes, the availability of professional schools. An index of educational options was constructed from a scale of places rated AAA, AA, B, C, and nonavailable resource. Data source was the National Center for Education Statistics and data were collected for the year 1977-78.

Educational Spending. Dollars per student spent on elementary education. Source was U.S. Department of Health and Human Services; data were collected for 1977.

Fortune 500 Headquarters. Raw count of the number of Fortune 500 headquarters located in metropolitan areas. Data were taken from "Fortune" magazine and collected for 1977-78. Forty-five Fortune 500 companies were not included because their headquarters are not located in major metropolitan areas.

Freeway Density. The number of freeway miles in metropolitan areas divided by the metropolitan land area. Data were collected from the U.S. Department of Transportation for the years 1977 and 1978.

House Spending. The average sales price for a home in metropolitan areas in 1976. Data were taken from the annual U.S. Bureau of the Census' survey of average house sales price in the U.S. metropolitan areas. Data were collected for 1976.

Labor Force 1977. The raw count of metropolitan labor force, 1977. Data source was the State and Metropolitan Area Data Book, 1977.

Major University. Dummy variable constructed using the highest ranked engineering and business schools in the country. Statistics compiled by the the U.S. Department of Education. Data were collected for 1975.

Spanish Population 1970. Raw count of Spanish-surnamed individuals in 1970 divided by 1970 population. Data source was the State and Metropolitan area Data Book, 1977. This variable was particularly problematic because in 1970 there was no agreed-upon definition of "Spanish-speaking" person. 1980 Census population counts are supposed to be significantly better than those reported in 1970.

1977 Unemployment Rate. Percent unemployment in metropolitan areas. Data source was the State and Metropolitan Area Data Book, 1977.

Percent of Unionized State Labor Force. Union membership as a percent of nonagricultural and military employment for 1976. Data were only available at the State level. Therefore, this measure is the percent of unionized labor force for States. Data source was the Handbook of Labor Statistics, 1979.

Industrial Utility Rates. Average State industrial utility rates, based on the average kilowatt-hour charge for industrial electrical supply. Data were for 1980. We used the data, despite the recent date of origin, because we felt that the utility rate trends were not likely to deviate substantially between the earlier and later periods. More importantly, we were interested in marginal rather than absolute differences. Data source was the State and Metropolitan Area Data Book, 1977.

Percent Voted Republican. Percent of the voting population who voted for a Republican presidential candidate in 1976. Data source was the State and Metropolitan Area Data Book, 1977. In cases where dominant party was Democratic, the difference was calculated and then assigned to the area.

Average Manufacturing Wage, 1977. Average weekly number of hours worked divided by the average weekly gross wages for manufacturing workers. Data source was the Employment and Earnings State and Area Series, U.S. Department of Labor, 1977. A second source, The Census of Manufacturers, table 4, was consulted in those cases where the data were not reported by the Department of Labor. The range across areas varied from approximately $4 to $8 per hour.

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